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LESSONS WITH PLANTS



LESSONS WITH PLANTS

SUGGESTIONS FOR SEEING AND
INTERPRETING SOME OF THE
COMMON FORMS OF VEGETATION

BY

L. H. BAILEY

With delineations from nature by
W. S. HOLDSWORTH
Assistant Professor of Drawing in the Agricultural
College of Michigan

SECOND EDITION

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INTRODUCTION

PLANTS are among the most informal of objects, but botany is popularly understood to be one of the most formal of the natural sciences. This is only another way of saying that plant-study is not always taught by a natural method; and this the writer believes to be true for the secondary schools, and it is the reason why he was willing to undertake the preparation of a book about plants for beginners, when urged to do so by the publishers. It is a common method to begin the study of plants by means of formal ideals—or definitions,—but the author believes that the proper way to begin it is by means of plants. The definition sets a model and tells the pupil what he shall see; the plant shows him what there is to be seen, and the definition follows. When one has studied a number of objects, he begins unconsciously to generalize and to arrange the impressions which he has received, and his conclusion is the only true definition for him.

The ways, then, in which this book may be used are as follows:

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1. By the teacher. It contains merely a few type lessons, for the double purpose of instructing the teacher and of suggesting a method of presenting the subject to pupils; and since the author cannot bring the plants with him, he brings good pictures, which are the next best things. If the book should ever fall into the hands of a teacher who is uninformed in plants, the author hopes that the teacher will master one of the observations, then lay the book aside and collect specimens similar to those discussed and present them to the scholars. The teacher should remember that the information which the pupil acquires is of far less value than the methods of acquiring it and the mental uplift which comes from the inspiration of the exercise. The author would be sorry if any teacher should feel that he must follow the methods or the order in this book, for every teacher—if he is a teacher—has methods of his own. The book only suggests; and it may aid him to overcome prejudice. It is not the object of the book to teach a science; it only indicates a way in which plants may be studied and the subject taught. There is no attempt, therefore, to give coördinate treatment to the different phenomena and attributes of vegetation. The teacher will be constantly foraging beyond the book, but, on the other hand, it may now and then supply an exercise when illustrative specimens cannot be secured. In the hands of a good teacher, therefore, the book may be used for any of the grades of the

secondary schools. There is no objection whatever to the pupil using the book. It is to be hoped that the book can do him no harm. But the teacher is advised to lay it aside after studying it, simply because a live teacher and a live plant are worth very much more than a book and a picture.

2. The pupil may use it in the same way that the teacher should. Many teachers to whom botany falls in the secondary schools have too many subjects on their hands to enable them to give adequate attention to any one of them; and some of them have tastes in other directions. Then give the pupil the book. Tell him to read a lesson; then let him collect the specimens and recite from the specimens, not from the book. The book will awaken his interest, and suggest what there is to be seen. There is a current notion that the pupil should be given the specimen and be told to find what there is to be learned about it, wholly without suggestions. The author does not believe in this method, particularly not for beginners. Pupils first need the inspiration of a teacher. They need a start. With the specimens alone, the great mass of pupils see nothing and become listless. It is not true that only those things are useful which one finds out for himself, else we could make little progress. But the pupil should find out something for himself; and more than all, he should enjoy the finding of it. In the present status of the secondary schools, the author expects that

if this book is used at all, it will be chiefly employed by the pupil and in the way here suggested.

3. The pupil may recite from the book, for enough of formal statement and definition may have crept into the work to enable it to be used as a simple text-book.

The purpose of the book, in other words, is to suggest methods of nature-study; and in order to still further explain what the author means by nature-study, a quotation is made from his recent leaflet, issued by the College of Agriculture of Cornell University, entitled "What is Nature-study?":

"It is seeing the things which one looks at, and the drawing of proper conclusions from what one sees. Nature-study is not the study of a science, as of botany, entomology, geology, and the like. That is, it takes the things at hand and endeavors to understand them, without reference to the systematic order or relationships of the objects. It is wholly informal and unsystematic, as the objects are which one sees. It is entirely divorced from definitions, or from explanations in books. It is therefore supremely natural. It simply trains the eye and the mind to see and to comprehend the common things of life; and the result is not directly the acquirement of science, but the establishing of a living sympathy with everything that is.

"The proper objects of nature-study are the things which one oftenest meets. To-day it is a stone; to-morrow it is twig, a bird, an insect, a leaf, a flower.

The child, or even the high school pupil, is first interested in things which do not need to be analyzed or changed into unusual forms or problems. Therefore, problems of chemistry and of physics are for the most part unsuited to early lessons in nature-study. Moving things, as birds, insects and mammals, interest children most, and seem to be the proper subjects for nature-study; but it is often difficult to secure specimens when wanted, especially in liberal quantity, and still more difficult to see the objects in perfectly natural conditions. Plants are more easily had, and are therefore more practicable for the purpose, although animals and minerals should by no means be excluded.

"If the objects to be studied are informal, the methods of teaching should be the same. If nature-study were made a stated part of a curriculum, its purpose might be defeated. The chief difficulty with our present school methods is the necessary formality of the courses and the hours. Tasks are set, and tasks are always hard. The best way to teach nature-study is, with no course laid out, to bring in whatever object may be at hand and to set the pupils at work. They see the thing, and explain its structure and its meaning. The exercise should not be long, not to exceed fifteen minutes at any time, and, above all things, the pupil should not look upon it as a recitation, and there should not be an examination. It should come as a rest exercise, whenever the pupils become list-

less. Ten minutes a day for one term, of a short, sharp and spicy observation upon plants, is worth more than a whole text-book of botany.

"The teacher should studiously avoid definitions, and the setting of patterns. The old idea of the model flower is a pernicious one, because it does not exist in nature. The model flower, the complete leaf, and the like, are inferences, and pupils should begin with things and not with ideas. In other words, the ideas should be suggested by the things, and not the things by the ideas. 'Here is a drawing of a model flower,' the old method says; 'go and find the nearest approach to it.' 'Go and find me a flower,' is the true method, 'and let us see what it is.'

"Every child, and every grown person too, for that matter, is interested in nature-study, for it is the natural method of acquiring knowledge. The only difficulty lies in the teaching, for very few teachers have had drill or experience in this informal method of drawing out the observing and reasoning powers of the pupil wholly without the use of text-books. The teacher must first of all feel the living interest in natural objects which it is desired the pupils shall acquire. If the enthusiasm is not catching, better let such teaching alone.

"All this means that the teacher will need helps. He will need to inform himself before he attempts to inform the pupil. It is not necessary that he become

a scientist in order to do this. He goes only as far as he knows, and then says to the pupils that he cannot answer the questions which he cannot. This at once raises the pupil's estimation of him, for the pupil is convinced of his truthfulness, and is made to feel—but how seldom is the sensation!—that knowledge is not the peculiar property of the teacher, but is the right of any one who seeks it. It sets the pupil to investigating for himself. The teacher never needs to apologize for nature. He is teaching because he is an older and more experienced pupil than his pupil is. This is just the spirit of the teacher in the universities to-day. The best teacher is the one whose pupils farthest outrun him. * * * * Now and then, take the children for a ramble in the woods or fields, or go to the brook or lake. Call their attention to the interesting things which are met—whether they are understood or not—in order to teach them to see, and to find some point of sympathy; for every one of them will some day need the solace and the rest which this nature-love can give. It is not the mere information which is valuable; that may be had by asking some one wiser than they, but the inquiring and sympathetic spirit is one's own.

"The pupils will find their lessons easier to acquire for this respite of ten minutes with a leaf or an insect, and the school-going will come to be less perfunctory. If drawing must be taught, set a good picture before

the pupils for study, and then substitute the object. composition is to be taught let the pupils write up what they have seen. After a time, give ten minutes now and then to asking the children what they saw on their way to school."

It is often said that a person may learn a good deal about plants with only a very ordinary hand lens. This is true; but he can also learn a good deal without any lens. It is not impossible that in the haste to give the pupil a microscope, we have forgotten the training of the natural eye; and it is upon the natural eye that the great mass of people must depend. These remarks are made simply to emphasize the fact again that much more depends upon the teaching power of the teacher than upon the mechanical equipment of the school-room. It will not be necessary for the pupil to have a lens in order to take the kind of work suggested in this book, but he ought to have one. There are two essentials in a pupil's microscope: a large field (not less than three-fourths inch across), and a size which will allow it to be carried in the pocket. Pupils generally think of a lens as a piece of school-room apparatus, like slates and pens are, but it should be a constant companion in the field. If it can be used in only one place, let that place be out of doors. These instruments magnify three diameters or less, and the number of lenses is two or three. For the use of advanced

pupils and specialists, higher powers and a smaller field are essential, but such expensive magnifiers are not needed in the common plant-study of the beginner.

It is a common mistake, in instructing beginners, to teach them too much at one exercise. Enough will be gained if the pupil's interest is merely awakened in some new direction. The younger the pupil, the more imperative is this caution not to overdo the instruction. It may be sufficient for one day to drop the suggestion that there are many shapes and sizes of leaves; then let the pupil observe and reflect.

It is to be feared that much of our nature-teaching and nature-literature aim at little more than the presentation of interesting information, or even the telling of entertaining stories; they are prone to pick out the most demonstrative and striking objects, and, by filling the pupil's mind with wonder for the curious and unusual, cause him to overlook the commoner things of equal interest and of greater educative value. The purely scientific teaching and literature, on the other hand, are apt to discourage the pupil by the obtrusion of set tasks, definitions and terminology. The writer believes that the language of botany,—the terminology,—should be picked up by the pupil as he goes along and as he needs it, in the same way that he acquires his common speech.

The greater number of persons can never become botanists, but most of them can have a living interest in

plants if properly taught in the beginning. It would seem, therefore, that the proper way to begin botany in the secondary schools is by study of the gross features of plants, not by dissections and microscope work. The study of type forms and anatomy and physiology is a subsequent matter, and is best suited to those pupils who evince a desire and an ability to specialize, or to pursue a science.

The foregoing remarks may be epitomized as follows:

We must first ask why we desire to teach natural history subjects in the primary and secondary schools. There can be but two answers: we teach either for the sake of imparting the subject itself, or for the sake of the pupil. When we have the pupil chiefly in mind, we broaden his sympathies, multiply his points of contact with the world, and thereby deepen his life; a graded and systematic body of facts is of secondary importance. In other words, when the teacher thinks chiefly of his subject, he teaches a science; when he thinks chiefly of his pupil, he teaches nature-study. The child always loves nature; but when he becomes a youth, and has passed the intermediate years in school, the nature-instinct is generally obscured and sometimes almost obliterated. The perfunctory teaching of science may be a responsible factor in this result. There seem to be four chief requisites in nature-study teaching, if the pupil is to catch inspiration from it:

1. The subject itself must interest the pupil. This

means that the instruction begin with the commonest things, with those which are actually a part of the pupil's life.

2. The pupil must feel that the work is his, and that he is the investigator.

3. Little should be attempted at a time. One thought or one suggestion may be enough for one day. The suggestion that insects have six legs is sufficient for one lesson. We obscure the importance of common things by cramming the mind with facts. When the pupil is taught to take systematic notes upon what the teacher says, it is doubtful if the lesson is worth the while, as nature-study. The pupil cannot be pushed into sympathy with nature.

4. The less rigid the system of teaching and the fewer the set tasks, the more spontaneous and, therefore, the better, is the result. A codified system of examinations will choke the life out of nature-study.

In this nature-study, it would seem to be unwise to rigidly grade the work, particularly as it is presented in a text-book. The teacher can grade or adapt the matter,—he can fill out the frame-work—as seems best for his pupils and conditions. The work must be consecutive, however, if it is to find a definite place in schools. That is, some general plan or scheme must be laid out; and in this direction it is hoped that this book of suggestions may be helpful. The first object of the book is to suggest methods, not to present facts. The liberal

use of pictures in the book will suggest to the teacher the importance of having an abundance of illustrative material for the exercises, letting the pupils see the things themselves, as far as practicable, no matter how common or familiar they may be; and it is an advantage to have the pupils collect the specimens. The pupil's living contact with common things will strengthen the bond between the school and the home.

These Lessons are an extension of the ideas embodied in the nature-study leaflets issued for the use of teachers by the College of Agriculture of the Cornell University; and these leaflets are, in turn, the direct outgrowth of "observation lessons" which were a part of the instruction given in itinerant schools of horticulture in New York state. Observations xiv. and lxi. are adapted from two of these leaflets. The leaflets have met with great demand from teachers in all grades of school work, not only in New York, but elsewhere. These publications have aimed to awaken an interest and curiosity on the part of the pupil by suggesting interesting topics to the teacher, and by indicating means of presenting the subjects.

The author is under the greatest obligations to Professor W. S. Holdsworth, of the Michigan Agricultural College, whose skilful hand and faithful eye have wrought most of the illustrations, and without whose coöperation the book would probably not have been

attempted. Professor C. F. Wheeler, of the same institution, has aided the artist at every point, and has attended to the selection of much of the material for the illustrations. He has also read all the proofs, and has taken the most helpful interest in the progress of the work. The proofs have also been read by Professor W. F. Ganong, of Smith College, Northampton, Massachusetts, whose coöperation was solicited in order that the book should not contradict recent studies in morphology. He has given most generous assistance, and has added greatly to any merit which the book may possess, but, in justice to him, the author must state that it has been impossible to incorporate all the useful suggestions and criticisms which he has made.

The author will be glad of any suggestions upon the matter or the method of the book.

L. H. BAILEY.

HORTICULTURAL DEPARTMENT, CORNELL UNIVERSITY,
ITHACA, NEW YORK, November 1, 1897.



SYNOPSIS

(The figures in parentheses are the numbers of paragraphs)

PART I

OBSERVATION	STUDIES OF TWIGS AND BUDS (pages 1-77)	PAGE
I.	The bud and the branch (1-5)	1
II.	The leaf-bud and the fruit-bud (6-9)	5
III.	The deflected axis of growth (10-15)	7
IV.	The struggle for existence in a tree top (16-20)	15
V.	Knots and knot-holes (21-23)	21
VI.	The fruit-spur (24-29)	25
VII.	Fruit-bearing, concluded (30-34)	32
VIII.	Characters in winter twigs (35-40a)	38
IX.	The opening of the buds (41-47)	44
X.	The opening of the buds, continued (48-56)	48
XI.	The opening of the buds, concluded (57-63a)	57
XII.	Arrangement of the buds (64-71)	63
XIII.	Expansion of the bark (72-77)	69
XIV.	A bit of history (78-80)	73

PART II

	STUDIES OF LEAVES AND FOLIAGE (pages 78-130)	
XV.	What is a leaf? (81-86)	78
XVI.	The parts of leaves (87-93)	80
XVII.	The compound leaf (94-104c)	87
XVIII.	Disguises of leaves (105-112a)	96

XX

SYNOPSIS

OBSERVATION	PAGE
XIX. Disguises of leaves, concluded (113-118d)	103
XX. The attachment of the leaf, and the insertion of the petiole (119-126)	110
XXI. The forms of leaves (127-133a)	115
XXII. Variation in leaves on the same plant, and on different plants of the same kind (134-138)	122

PART III

STUDIES OF FLOWERS (pages 131-249)

XXIII. What is a flower? (139-146)	131
XXIV. What is a flower? concluded (147-152)	135
XXV. The parts of the pistil (153-159b)	139
XXVI. The stamens (160-165)	145
XXVII. The insertion of the flower (166-170)	150
XXVIII. Reinforced flowers (171-175)	152
XXIX. Diclinous flowers (176-183a)	156
XXX. Diclinous flowers, continued (184-188)	163
XXXI. Diclinous flowers, concluded (189-193)	168
XXXII. The dandelion (194-200)	171
XXXIII. The compositous tribes (201-208)	177
XXXIV. Forms of the perianth (209-213)	183
XXXV. The arrangement of the flowers (214-221a)	188
XXXVI. The arrangement of the flowers, concluded (222-227)	193
XXXVII. The kinships of the flower (228-235a)	197
XXXVIII. Particular types of flowers (236-240a)	206
XXXIX. Particular types of flowers, continued (241-247a)	209
XL. Particular types of flowers, continued (248-253)	215
XXLI. Particular types of flowers, continued (the orchids) (254-258c)	222
XLII. Particular types of flowers, continued (grass-like plants) (259-263a)	226
XLIII. Particular types of flowers, concluded (sedges) (264-268)	230
XLIV. Cross-fertilization (269-276)	234
XLV. Cross-fertilization, concluded (277-281)	239
XLVI. The crossing of plants (282-288)	246

SYNOPSIS

xxi

PART IV

STUDIES OF THE FRUCTIFICATION (pages 250-315)

OBSERVATION	PAGE
XLVII. The akene (289-296)	250
XLVIII. The drupe (297-302)	255
XLIX. Simple pods (303-309)	259
L. Compound pods (310-318)	263
LI. Key-fruits (319-322)	270
LII. Berries (323-327)	273
LIII. Reinforced fruits (328-333)	278
LIV. Reinforced fruits, concluded (334-339)	284
LV. Apples and their like (340-349)	289
LVI. Pumpkins and squashes (350-356)	295
LVII. Tomatoes and oranges (357-363a)	300
LVIII. Mulberries and figs (364-369)	303
LIX. Pines and their kin (370-376b)	306
LX. Influence of pollen upon the fruit (377-381a)	311

PART V

STUDIES OF THE PROPAGATION OF PLANTS (pages 316-380)

LXI. How the squash plant gets out of the seed (382-392)	316
LXII. Germination of the onion (393-398a)	323
LXIII. Germination of beans (399-405a)	327
LXIV. What is a seed? (406-411)	331
LXV. The dispersion of seeds (412-423d)	336
LXVI. Ferns (424-428b)	342
LXVII. Mushrooms and their kind (429-437b)	347
LXVIII. Bulbs, bulblets and buds (438-446)	353
LXIX. Corms and rootstocks (447-453a)	358
LXX. Tuberous parts (454-458a)	362
LXXI. Runners and layers (459-463)	367
LXXII. The mangrove (464-470)	371
LXXIII. Cuttings and grafts (471-479)	374

PART VI

STUDIES OF THE BEHAVIORS AND HABITS OF PLANTS (pp. 381-424)

OBSERVATION	PAGE
LXXIV. The struggle for existence (480-485a)	381
LXXV. The duration of plants (486-493a)	386
LXXVI. The stature and habit of plants (494-499a)	388
LXXVII. How some plants get up in the world (500-507)	396
LXXVIII. Various movements of plants (508-512)	402
LXXIX. Epiphytes, parasites and saprophytes (513-518)	406
LXXX. Plant societies (519-524)	410
LXXXI. Records of the seasons and the years (525-530)	414
LXXXII. The breeding of plants (531-535a)	418
LXXXIII. Upon what does a plant live? (536-543a)	421

PART VII

STUDIES OF THE KINDS OF PLANTS (pages 425-444)

LXXXIV. Species (544-549)	425
LXXXV. The naming of species (550-555c)	427
LXXXVI. The classification of species (556-564)	432
LXXXVII. The preserving of plants (565-570d)	437

APPENDIX

SUGGESTIONS AND REVIEWS (pages 445-472)

1. Suggestions upon pedagogical methods	445
2. Books	446
3. Classification	447
4. Remarks upon evolution and the interpretation of nature	448
5. The growing of plants	448
6. Glossary	455

INDEX (pages 473-491)

REGISTER OF ILLUSTRATIONS

FIG.	PAGE
1 Apple twig in winter.....	2
2 The same twig in fall before the leaves have fallen	2
3 Apple twig showing formation of fruit-buds	6
4 Apple twig in winter, showing deflected axis of growth	8
5 The same twig before the falling of the leaves.....	8
6 Twigs of dogwood, <i>Cornus Baileyi</i>	9
7 Twin terminal buds of red elder, <i>Sambucus racemosa</i>	10
8 Shoots of common lilac	10
9 Lilac twig, to show deflected axis	11
10 Twig of haw, <i>Viburnum Lentago</i>	12
11 Bush of sumac, <i>Rhus typhina</i>	13
12 Spray of white oak, <i>Quercus alba</i>	15
13 Spray of Norway maple, <i>Acer platanoides</i>	16
14 Same.....	17
15 Young tree of black cherry, <i>Prunus serotina</i>	18
16 Tree of sweet garden cherry, <i>Prunus Avium</i>	19
17 Tree of sour garden cherry, <i>Prunus Cerasus</i>	20
18 19 Knots in oak limbs	21
20 Knot in a hemlock log.....	22
21 Knot in a white oak tree.....	22
22 Healing of a wound on an apple tree	23
23 Twigs of apple, to show spurs	25
24 Spur on an apple twig.....	26
25 Spurs of crab apple, <i>Pyrus baccata</i>	27
26 Old spur of pear	27
27 Spur of plum.....	31
28 Twig of peach	33
29 30 Twigs of peach.....	34
31 Young fruit of peach	35
32 Twig of cultivated gooseberry, <i>Ribes oxycanthoides</i>	35
33 Twig of black currant, <i>Ribes nigrum</i>	36
34 Twig of dwarf juneberry, <i>Amelanchier oblongifolia</i>	37
35 Twig of balm of Gilead, <i>Populus candicans</i>	38
36 Twig of Japan walnut, <i>Juglans Sieboldiana</i>	39
37 Leaf-scar of sumac, <i>Rhus glabra</i>	39
38 Leaf-scars of dahlia.....	40
39 Leaf attachment in <i>Arundo Donax</i>	40
40 Green-briar, <i>Smilax rotundifolia</i>	41

FIG.	PAGE
41 Showing leaf-attachment of Sabal Palmetto	41
42 Twigs of three hickories,— <i>Hicoria microcarpa</i> , <i>H. ovata</i> , <i>H. glabra</i>	42
43 Twigs of willows,— <i>Salix cordata</i> , <i>S. rostrata</i> , <i>S. discolor</i>	43
44 Vernation of crab apple, <i>Pyrus baccata</i>	45
45 Same	47
46 Flower-cluster of apple	49
47 Flowers of apricot	49
48 Section of flower-bud of apricot	50
49 Opening bud of pear	50
50 Vernation of Norway maple, <i>Acer platanoides</i>	51
51 Vernation of black currant, <i>Ribes nigrum</i>	52
52 Bud of <i>Rhododendron Catawbiense</i>	53
53 Flowering of the quince	54
54 Twig of quince	55
55 Branch of hickory, <i>Hicoria microcarpa</i>	56
56 Vernation of honeysuckle	58
57 Vernation of peach	58
58 Plaited leaf of blue palmetto, <i>Chamaerops hystrix</i>	59
59 Vernation of tulip tree, <i>Liriodendron Tulipifera</i>	59
60 Vernation of horse-chestnut	60
61 Vernation of a fern	61
62 Linnæus' diagrams of vernation	62
63 Leaves of <i>Galium Aparine</i>	64
64 Phyllotaxy of elm	66
65 Phyllotaxy of plum	66
66 Phyllotaxy of plum	67
67 Fasciation of <i>Ailanthus glandulosus</i>	68
68 69 Expansion of bark of elm	70
70 Record of an apple twig	74
71 Leaf of dewberry, <i>Rubus trivialis</i>	78
72 Leaf of Lombardy poplar, <i>Populus nigra</i> var. <i>Italica</i>	79
73 Leaves of apple	79
74 Leaf of wheat	80
75 Leaves of <i>Lonicera ciliata</i>	81
76 Leaf of black walnut, <i>Juglans nigra</i>	81
77 Leaves of live oak, <i>Quercus virens</i>	82
78 Leaf of willow, <i>Salix adenophylla</i>	82
79 Leaf of Virginia creeper, <i>Ampelopsis quinquefolia</i>	83
80 81 Leaves of wild grape, <i>Vitis bicolor</i>	84
82 Leaves of garden bean, <i>Phaseolus vulgaris</i>	85
83 Leaf of Canada thistle, <i>Cnicus arvensis</i>	86
84 Leaf of poison ivy, <i>Rhus Toxicodendron</i>	88
85 Leaf of poison sumac, <i>Rhus venenata</i>	89
86 Leaf of <i>Jeffersonia diphylla</i>	89
87 Leaf of <i>Dicentra Canadensis</i>	90
88 Leaf of <i>Acacia Arabica</i>	91
89 Shoot of Currant tomato, <i>Lycopersaleum pimpinellifolium</i>	92
90 Leaf of Mikado tomato	93

REGISTER OF ILLUSTRATIONS

XXV

FIG.	PAGE
91 Leaf of dahlia	94
92 Sprig of <i>Veronica peregrina</i>	96
93 Leaf of common pea	97
94 95 Leaves of <i>Cobaea scandens</i>	98
96 Leaf of <i>Sarracenia variolaris</i>	99
97 Leaf of orange	100
98 Leaf of <i>Ægle</i> (or <i>Citrus</i>) <i>trifoliata</i>	100
99 Leaves of barberry	101
100 Sprig of Russian thistle, <i>Salsola Kali</i> var. <i>Tragus</i>	101
101 Common asparagus	102
102 Spray of florists' smilax, <i>Asparagus medeoloides</i>	104
103 Phyllodia of <i>Acacia longifolia</i>	105
104 Phyllodia of <i>Acacia armata</i>	105
105 Leaves of <i>Pinus Strobus</i>	106
106 Spray of <i>Lonicera Caprifolium</i>	111
107 Leaf of mullein, <i>Verbascum Thapsus</i>	111
108 Amplexicaul leaves of <i>Aster levis</i>	112
109 Perfoliate leaves of <i>Potamogeton perfoliatus</i>	112
110 Sheath of rhubarb	112
111 Leaf of <i>Memispermum Canadense</i>	113
112 Leaf of <i>Tropeolum majus</i>	113
113 Spray of red pepper or capsicum	115
114 Same	116
115 Leaf of wild chestnut	117
116 Leaf of catnip, <i>Nepeta Cataria</i>	118
117 Linnæus' diagrams of leaves	120
118 Leaves of birch, <i>Betula alba</i>	121
119 Leaves of smilax	122
120 Leaves of Russian mulberry	123
121 122 Sprigs of red cedar, <i>Juniperus Virginiana</i>	124
123 Tomato foliage	125
124 Tomato foliage	126
125 Tomato foliage	127
126 Tomato foliage	128
127 Leaf of common chrysanthemum	129
128 Leaf of feverfew, <i>Chrysanthemum Parthenium</i>	129
129 Leaf of <i>Chrysanthemum frutescens</i>	130
130 Leaf of <i>Chrysanthemum fœniculaceum</i>	130
131 Flower of <i>Hepatica triloba</i>	131
132 Akenes of <i>Hepatica triloba</i>	132
133 134 Flowers of mustard	133
135 Siliques of mustard	134
136 Pistillate flowers of <i>Salix discolor</i>	136
137 Staminate flowers of <i>Salix discolor</i>	137
138 Tulips	140
139 Apple flowers	141
140 Pistil of catnip, <i>Nepeta Cataria</i>	141
141 Akenes of <i>Hepatica triloba</i>	142

FIG.	PAGE
142 Ovary of tulip	142
143 Flower of corn-cockle, <i>Lychnis Githago</i>	143
144 Plum flowers	144
145 Ovary of <i>Podophyllum peltatum</i>	144
146 Flower of currant, <i>Ribes rubrum</i>	145
147 Stamens of <i>Nymphaea reniformis</i>	146
148 Flower of <i>Lilium Canadense</i>	146
149 Stamen of <i>Azalea nudiflora</i>	147
150 Flower and stamens of barberry.....	147
151 Flower of <i>Salvia coccinea</i>	148
152 Carnation	148
153 Flower of <i>Hepatica triloba</i>	148
154 Flowering dogwood, <i>Cornus florida</i>	154
155 Paper birch, <i>Betula papyrifera</i>	155
156 Catkin of <i>Betula lutea</i>	157
157 Blue-beech, <i>Carpinus Caroliniana</i>	158
158 Catkins of filbert, <i>Corylus Avellana</i>	158
159 Flowers of hazel, <i>Corylus rostrata</i>	158
160 <i>Hicoria microcarpa</i>	159
161 162 Flowers of Hubbard squash.....	160
163 Spray of cucumber.....	163
164 Spray of gherkin, <i>Cucumis Anguria</i>	164
165 <i>Carex torta</i>	165
166 <i>Carex tribuloides</i> var. <i>cristata</i>	166
167 Ear of maize	167
168 Calla	168
169 Head of dandelion	172
170 Floret of dandelion.....	172
171 Dandelion	173
172 Leaves of dandelion.....	175
173 <i>Rudbeckia hirta</i>	178
174 Fullers' teasel, <i>Dipsacus Fullonum</i>	180
175 Floret of aster.....	181
176 <i>Campanula rotundifolia</i>	182
177 <i>Phlox glaberrima</i>	182
178 Flower of eggplant.....	183
179 Flowers of foxglove	183
180 Flower of catnip, <i>Nepeta Cataria</i>	184
181 Flower of <i>Catalpa speciosa</i>	184
182 Flower of lily-of-the-valley.....	185
183 <i>Narcissus</i>	186
184 Raceme of lily-of-the-valley	187
185 Raceme of currant, <i>Ribes rubrum</i>	188
186 Plantain spike.....	189
187 Umbel of carrot.....	190
188 Inflorescence of arrow-leaf, <i>Sagittaria variabilis</i>	191
189 Panicle of june-grass, <i>Poa pratensis</i>	192
190 Buckwheat.....	194

REGISTER OF ILLUSTRATIONS

xxvii

FIG.	PAGE
191 Basswood, <i>Tilia Americana</i>	194
192 Wild crab-apple, <i>Pyrus coronaria</i>	195
193 Elder, <i>Sambucus Canadensis</i>	198
194 Bud on pear stem.....	199
195 Flower of <i>Nymphaea reniformis</i>	200
196 Flower of canna.....	201
197 Carpels of <i>Sterculia platanifolia</i>	202
198 Double carnation.....	203
199 Transformations in tulip.....	204
200 Double-flowering almond, <i>Prunus Japonica</i>	205
201 Sweet pea.....	207
202 Androecium and gynoecium of sweet pea.....	207
203 <i>Viola cucullata</i>	210
204 205 Flowers of <i>Aristolochia Sipho</i>	211
206 Grape Myrtle, <i>Lagerstromia Indica</i>	213
207 <i>Adlumia cirrhosa</i>	214
208 Flowers of grape.....	215
209 <i>Passiflora edulis</i>	217
210 <i>Euphorbia corollata</i>	218
211 Flowers of <i>Acer rubrum</i>	219
212 <i>Lemna minor</i>	220
213 <i>Cypripedium spectabile</i>	221
214 Column of <i>cypripedium</i>	222
215 <i>Pogonia ophioglossoides</i>	224
216 Bullrush, <i>Juncus effusus</i>	224
217 Rye.....	225
218 Flower of June-grass, <i>Poa pratensis</i>	227
219 Flowers of maize.....	228
220 <i>Carex tribuloides</i> var. <i>cristata</i>	229
221 Same.....	230
222 Same.....	231
223 <i>Carex lurida</i>	232
224 Perigynium of <i>Carex lurida</i>	233
225 Racheola of <i>carex</i>	233
226 <i>Phlox glaberrima</i>	235
227 Flower of garden columbine.....	237
228 Crowfoot, <i>Ranunculus acris</i>	238
229 Flowers of <i>primula</i>	239
230 Pollination of sweet pea.....	241
231 Pollination of <i>asclepias</i>	243
232 Cleistogamous flowers of <i>Dalibarda repens</i>	244
233 Emasculation of <i>maurandia</i>	247
234 Protecting a crossed flower.....	248
235 Bag for protecting crossed flowers.....	249
236 Akene of <i>Clematis verticillaris</i>	252
237 Burs of <i>Cynoglossum officinale</i>	252
238 Strawberry flower.....	253
239 Strawberry.....	253

FIG.	PAGE
240 Strawberry "nubbin"	254
241 Frost-injured blackberries	255
242 Proliferous strawberry	256
243 Black raspberry	256
244 245 Young fruits of apricot	257
246 Multiple peach	258
247 Fruits of columbine	260
248 Bean pod	261
249 Jeffersonia pod	262
250 Lilac pod	263
251 Castor bean pod	264
252 Azalea pod	264
253 Pod of Hibiscus Syriacus	265
254 Pod of funkia	265
255 Boll of cotton	266
256 Pod of morning-glory	266
257 Pod of mignonette	267
258 Pod of balsam	267
259 Pod of balsam exploding	268
260 Fruit of Cardiospermum Halicacabum	268
261 Legumes of daubentonia	269
262 Samara of Acer saccharinum	271
263 Samara of Acer saccharinum var. nigrum	271
264 Young fruits of Negundo aceroides	272
265 Samara of Ptelea trifoliata	273
266 Key of white ash, Fraxinus Americana	273
267 Key of black ash, F. sambucifolia	273
268 Fruit of Ulmus Americana	273
269-272 Fruits of elms,—Ulmus fulva, U. racemosa, U. alata, and U. montana, respectively	274
273 Scuppernong grape, Vitis rotundifolia	275
274 Fruits of Caulophyllum thalictroides	276
275 Corn-cockle, Lychnis Githago	276
276 Same	277
277 Husk-tomato, Physalis Peruviana	278
278 279 Agrimonia Eupatoria	279
280 Witch-hazel, Hamamelis Virginiana	280
281 Young fruits of cocoa-nuts, Cocos nucifera	281
282-290 Acorns,—Quercus alba, Q. macrocarpa, Q. Prinus, Q. bicolor, Q. coccinea, Q. tinctoria, Q. rubra, Q. virens, Q. pedunculata, respectively	282-4
291 Hickory-nut, Hicoria laciniosa	285
292 Butternut, Juglans cinerea	286
293 Chestnut, Castanea dentata (Americana)	287
294-296 Sections of apple fruit	287-8
297 Bract on an apple fruit	289
298 Medlar, Mespilus Germanica	289
299 Different forms of apples	291
300 Gherkin, Cucumis Anguria	291

REGISTER OF ILLUSTRATIONS

xxix

FIG.	PAGE
301 May-pop, <i>Passiflora incarnata</i>	295
302-304 Turban squash	296-7
305 Peduncle of <i>Cucurbita maxima</i>	298
306 Peduncle of <i>Cucurbita Pepo</i>	298
307 Peduncle of <i>Cucurbita moschata</i>	299
308-310 Tomato fruits	300-301
311 Turk's-cap tomato	302
312 Flower of navel orange	302
313 Fruit of orange	302
314 Navel orange.....	303
315 316 Flowers and fruit of white mulberry.....	308
317 Fruit of red mulberry	304
318 319 Fruits of common fig	304
320 Staminate cone of <i>Pinus rigida</i>	306
321 Pistillate cone and flowers of <i>Pinus Austriaca</i>	307
322 <i>Pinus rigida</i>	308
323 324 Cones of <i>Pinus clausa</i>	309-310
325 Imperfectly fertilized fruit of tomato	312
326 Non-fertilized apple	313
327 Non-fertilized eggplant.....	314
328-341 Germination of squash	316-322
342 Sprouting of onion seed.....	323
343-347 Germination of onion.....	324-326
348 Germination of bean.....	327
349 Germination of Scarlet Runner bean, <i>Phaseolus multiflorus</i>	327
350 Seed of bean	331
351 Cocoa-nut	332
352 Bean laid open.....	333
353 Scarlet Runner bean laid open.....	333
354 Onion seed	334
355 Buckwheat seed	334
356 Pecan.....	335
357 Piece of <i>Adiantum pedatum</i>	342
358 Piece of <i>Aspidium marginatum</i>	343
359 Portions of fronds of <i>Onoclea sensibilis</i>	344
360 Diagram to illustrate a fern frond.....	344
361 Scouring-rush, <i>Equisetum hyemale</i>	345
362 <i>Lycopodium complanatum</i>	345
363 <i>Lycopodium lucidulum</i>	345
364 Moss, <i>Polytrichum commune</i>	346
365 366 Common mushroom, <i>Agaricus campestris</i>	348
367 <i>Amanita phalloides</i>	351
368 369 Bulbs of Easter lily.....	352
370 Onions.....	353
371 Top onions.....	354
372 House-leek, <i>Sempervivum tectorum</i>	354
373 Cabbage.....	356
374 Winter bud of <i>Anacharis Canadensis</i>	357

FIG.	PAGE
375 Winter bud of <i>Myriophyllum spicatum</i>	357
376 Corm of <i>gladiolus</i>	358
377 Rhizome of <i>Agrimonia Eupatoria</i>	359
378 Rhizome of <i>Smilacina racemosa</i>	360
379 Rhizome of quack-grass, <i>Agropyrum repens</i>	361
380 Potato.....	362
381 Sweet potato.....	363
382 Salsify.....	364
383 Root of <i>Phaseolus multiflorus</i>	364
384 Growth of old potato.....	365
385 Hill of potatoes.....	366
386 Layer of <i>Carex tribuloides</i>	367
387 Runner of strawberry.....	368
388 Stolon of black raspberry.....	369
389 Suckers of red raspberry.....	370
390-395 Various parts of mangrove, <i>Rhizophora Mangle</i>	371-374
396 Leaf-colony of <i>Bryophyllum calycinum</i>	375
397 398 <i>Begonia phyllomanica</i>	376-7
399 400 Cuttings of geranium.....	378
401 Leaf-cutting of rex begonia.....	378
402 403 Root-cuttings of horse-radish.....	378-9
404 Graft.....	379
405 406. Propagating devices.....	380
407 Fruits of <i>Symphoricarpos vulgaris</i>	381
408 Turnips.....	382
409 Mayflower, <i>Epigaea repens</i>	389
410 Tree of <i>Hickoria glabra</i>	391
411 Tree of <i>Hickoria microcarpa</i>	391
412 Roots of orchard grass, <i>Dactylis glomerata</i>	392
413 Roots of clover, <i>Trifolium pratense</i>	392
414 Trees of various Japanese plums.....	395
415 Japanese hop, <i>Humulus Japonicus</i>	397
416 417 Morning-glory, <i>Ipomoea purpurea</i>	397
418 Tendril of cucumber.....	398
419 Tendrils of cassabanana, <i>Sicana odorifera</i>	399
420 Tendril of <i>Ampelopsis tricuspidata</i>	400
421 Leaf of <i>Clematis Virginiana</i>	401
422 423 Leaves of <i>Oxalis Bowiciana</i>	403
424 <i>Hepatica acutiloba</i>	404
425 Sensitive plant, <i>Mimosa pudica</i>	405
426 427 American mistletoe, <i>Phoradendron flavescens</i>	407
428 Dodder, <i>Cuscuta Gronovii</i>	408
429 Indian-pipe, <i>Monotropa uniflora</i>	409
430 <i>Dahlia variabilis</i> , wild and improved.....	420
431 Girdled stem	423
432 <i>Acer saccharinum</i> var. <i>nigrum</i>	429
433 <i>Acer saccharinum</i>	430
434 <i>Carolus Linnaeus</i>	433

REGISTER OF ILLUSTRATIONS

XXXi

<i>FIG.</i>	<i>PAGE</i>
435 Asa Gray	435
436 Herbarium sheet	438
437 Herbarium label	439
438 Portable press	440
439 Corner in an herbarium.....	444
440 441 Diagrams to show poor and good planting.....	446, 450
442 A verdurous border	451
443-446 Planting of school-grounds.....	453-454

[REDACTED]



PART I

STUDIES OF TWIGS AND BUDS

I. THE BUD AND THE BRANCH

1. A twig cut from an apple tree in early spring is shown in Fig. 1. The most hasty observation shows that it has various parts or members. It seems to be divided at the point *f* into two parts. It is evident that the portion from *f* to *h* grew last year, and that the portion below *f* grew two years ago. The buds upon the two parts are very unlike, and these differences challenge investigation.

2. In order to understand this seemingly lifeless twig, it will be necessary to see it as it looked late last summer (and this condition is shown in Fig. 2). The portion from *f* to *h*,—which has just completed its growth,—is seen to have only one leaf in a place. In every axil (or angle which the leaf makes when it joins the shoot) is a bud. The leaf starts first, and as the season advances the bud forms in its axil.



FIG. 1.
An apple twig.



FIG. 2.
Same twig before leaves fell.

When the leaves have fallen, at the approach of winter, the buds remain, as seen in Fig. 1. Every bud on the last year's growth of a winter twig, therefore, marks the position occupied by a leaf when the shoot was growing.

3. The portion below *f*, in Fig. 2, shows a wholly different arrangement.

The leaves are two or more together (*a a a a*), and there are buds without leaves (*b b b b*). A year ago this portion looked like the present shoot from *f* to *h*,—that is, the leaves were single, with a bud in the

axil of each. It is now seen that some of these bud-like parts are longer than others, and that the longest ones are those which have leaves. It must be because of the leaves that they have increased in length. The body *c* has lost its leaves through some accident, and its growth has ceased. In other words, the parts at *a a a a* are like the shoot *f h*, except that they are shorter, and they are of the same age. One grows from the end or terminal bud of the main branch, and the others from the side or lateral buds. Parts or bodies which bear leaves are, therefore, branches.

4. The buds at *b b b b* have no leaves, and they remain the same size that they were a year ago. They are dormant. The only way for a mature bud to grow is by making leaves for itself, for a leaf will never stand below it again. The twig, therefore, has buds of two ages,—those at *b b b b* are two seasons old, and those on the tips of all the branches (*a a a a, h*), and in the axil of every leaf, are one season old. It is only the terminal buds which are not axillary. Buds are buds only so long as they remain dormant. When the bud begins to grow and to put forth leaves, it gives rise to a branch, which, in its turn, bears buds.

5. It will now be interesting to determine why

certain buds gave rise to branches and why others remained dormant. The strongest shoot or branch of the year is the terminal one (*fh*). The next in strength is the uppermost lateral one, and the weakest shoot is at the base of the twig. The dormant buds are on the under side (for the twig grew in a horizontal position). All this suggests that those buds grew which had the best chance,—the most sunlight and room. There were too many buds for the space, and in the struggle for existence those which had the best opportunities made the largest growths. This struggle for existence began a year ago, however, when the buds upon the shoot below *f* were forming in the axils of the leaves, for the buds near the tip of the shoot grew larger and stronger than those near its base. The growth of one year, therefore, is very largely determined by the conditions under which the buds were formed the previous year.

SUGGESTIONS.—At whatever time of year the pupil takes up the study of branches, he should look for three things: the ages of the various parts, the relative positions of the buds and leaves, the different sizes of similar, or comparable buds. If it is late in spring or early in summer he should watch the development of the buds in the axils, and he should determine (as inferred in 5) if the strength or size of the bud is in any way related to the size and vigor of the subtending (or supporting) leaf. Upon leafless twigs, the sizes of buds should also be noted, and the sizes of the former leaves may be inferred from the size of the leaf-scar (below the bud). The pupil should keep in mind the fact

of the struggle for food and light, and its effects upon the developing buds.

II. THE LEAF-BUD AND THE FRUIT-BUD

6. Another apple branch is shown in Fig. 3. It seems to have no slender last year's growth, as Figs. 1 and 2 have at *f h*. It therefore needs special attention. It is first seen that the "ring" marking the termination of a year's growth is at *a*. There are dormant buds at *b b*. The twig above *a* must be more than one year old, however, because it bears short lateral branches at *e e*. If these branchlets are themselves a year old (as they appear to be), then the portion *f g* must be a similar branch, and the twig itself (*a f*) must be two years old. The ring marking the termination of the growth of year before last is therefore at *f*. In other words, a twig is generally a year older than its oldest branches.

7. The buds *c c* are larger than the dormant buds (*b b*). That is, they have grown; and if they have grown, they are really branches, and leaves were borne upon their little axes in the season just past. The branchlets *d d d* are larger (possibly because the accompanying leaves were more exposed to light) and *e e* and *g* are still larger. For some reason the growth of this



twig was checked last year, and all the branches remained short. We find, in other words, that there is no necessary length to which a branch shall grow, but that its length is dependent upon local or seasonal conditions.

8. There are other and more important differences in this shoot. The buds terminating the branches (*e e g*) are larger and less pointed than the others are. If they were to be watched as growth begins in the spring, it would be seen that they give rise to both flowers and leaves, while the others give only leaves. In other words, there are two kinds of buds, fruit-buds and leaf-buds; and checking the growth induces fruitfulness.

9. If the buds on the ends of the branchlets *e e g* produce flowers, the twig cannot increase in length; for an apple is invariably borne on the end of a branch, and therefore no terminal bud can form there. If growth takes place upon the twig next year, therefore, it must arise from one of the lower or leaf-buds. The buds upon the branchlets *d d d* will stand the best chance of continuing the growth of the twig, for

FIG. 3.
Formation of
fruit-buds.

they are largest and strongest, and are most exposed to sunlight. These failing, the opportunity will fall to one or both of *cc*; and these failing, the long-waiting dormant buds may find their chance to grow. In other words, there are more buds upon any twig than are needed, but there is, thereby, a provision against emergencies.

SUGGESTIONS.—The pupil should give himself some practice in determining or locating the rings marking the annual lengths of growth. A good way to do this is to choose some tree of known age (as a fruit tree or shade tree which has been planted but a few years), and endeavor to account for all the years' growths. He should also endeavor to find out how long the dormant buds may live upon any tree. He should attempt to determine if it is true that a moderate growth (so long as the tree remains healthy) tends to make the tree bear. Those persons who have access to vineyards should determine whether the most prolific canes are those of medium size and which do not run off to great lengths on the wires. Examine orchards for this purpose. Many pupils have heard that driving nails into trees tends to make them bear, and the result may have been attributed to some influence which the iron is assumed to exert upon the plant; but if it is true that such practice induces fruitfulness, the pupil may be able to suggest an explanation of it. Let the pupil also determine whether dormant buds ever grow when the branch is injured above them.

III. THE DEFLECTED AXIS OF GROWTH

10. It is evident, from the foregoing observations, that the twig in Fig. 3 cannot continue its growth in a straight or continuous line. Fig. 4

is a sequel. (The foliage of this twig, as seen the previous fall, is accurately drawn in Fig. 5.)



FIG. 4.

A forking twig.



FIG. 5.

The leafage of the twig shown in Fig. 4.

The terminations of years' growths are at *c e* and *b*. Three years ago the terminal bud was at *c*, and it was a fruit-bud, for the scars of the

old flowers are seen on the squared or truncate end. While flowers were bearing on this place (two years ago), the two lateral buds gave rise to branches. One of these branches grew to *b*, and was broken off by some accident; the other grew to *e*, and there made a fruit-bud. Last year a lateral bud gave rise to the branch *b i*, and two lateral buds gave the branches *e f* and *e h*. When plants bear flowers from the terminal buds of the growing shoots, they cease making a leader or central trunk, but branch diffusely.

11. Twigs of one of the bushy dogwoods or osiers are seen in Fig. 6. These were cut in early spring, and, therefore, show what took place the year before. The one at the right bore a cluster of flowers last year, for the remains of the old bunch still persists. As this cluster was borne upon the very tip of the twig, no terminal bud could form to continue the direct

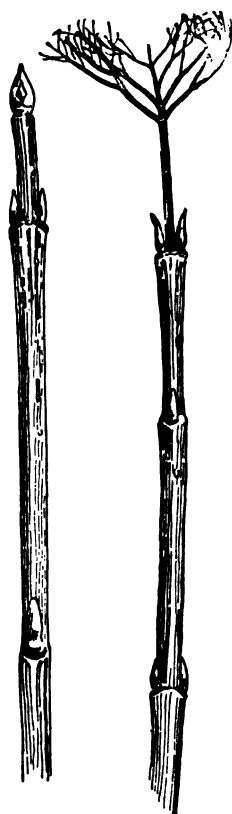


FIG. 6.
Shoots of a dogwood.



FIG. 7.

Twin terminal buds of the red elder.

growth of the twig this year. Therefore, the uppermost lateral buds become terminal, and each will compete with the other when growth begins, and the twig may become forked. Continuously forking woody plants are shrubs (or bushes), because they can have no central axis or trunk.

12. The shoot on the left, in Fig. 6, has made a single terminal bud. It is the end of a long, straight shoot or twig. It has not yet arrived at the flowering age. If, however, this terminal bud is a flower-bud, the forking of the branch will begin in the present year. In other words, this dogwood makes long, straight shoots until the flowering stage arrives, at which time it begins



FIG. 8.

Shoots of lilac.

a distinct method of branching.

12a. Can these remarks be made for most bushes? That is, do they make single terminal buds the first year or two from the seed, and afterwards begin a new habit of bud-bearing? If the pupil does not have access to young plants, he may examine the sprouts or "suckers" which spring from the roots of common bushes, as lilacs, roses, spireas, osiers, willows, barberries, privets, and the like. He may also study the horse-chestnut.

13. Some bushes seldom make single terminal buds. The red elder (Fig. 7) is one. In this case, therefore, it would seem as if the forking system of growth must commence at the very beginning of the plant's history. The lilac is a similar case. Fig. 8 shows the shoots just pushing out from the ends of "suckers" which spring from the ground. The specimen at the right shows the twin shoots, but one is stronger than the other. That is, in the struggle for existence one has the start. The sample at the left shows only one shoot, but the other bud, which has lost its opportunity, is seen at



FIG. 9.

A bearing lilac shoot.

the base of the stronger shoot (*a*). The lilac, therefore, gets up in the world by a process of suppression. This suppression begins the very year in which the buds are forming, for we have already seen (Fig. 3) that companion

buds are generally unlike; sometimes this early suppression goes so far that one bud never has an opportunity to fully develop.

14. In the fall, the old seed-pods of the lilac still persist on the bush. They are shown in Fig. 9. That is, both the terminal buds upon this shoot gave clusters of flowers, and it rested with the lower pairs of buds to continue the growth. Two of these pairs have made the effort, while the buds below them remain dormant and will never grow unless some injury should

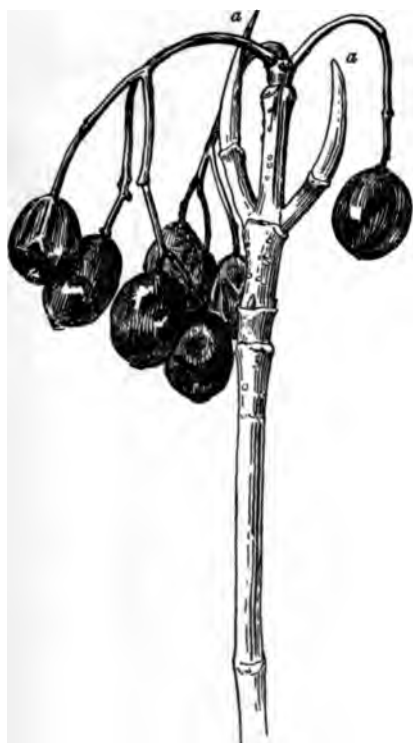


FIG. 10.

Winter twig of black haw, showing the side buds at *a*.

befall the shoots above. Each of these four shoots has two terminal buds, and each of the shoots is unlike the other.

It is easy to see that the shoot *a* is to become the head of the family. Fig. 10 will suggest investigation of the common black haw or viburnum.

Fig. 11 is a sumac bush, with its zigzag and forking growths; and the terminal clusters of seeds explain how the forking has arisen. The forks are most apparent at the tips of the branches; this only means

that many of the older branches have perished, and the remaining half of the fork has resulted in a zigzag growth. Irregular development among branches is the result of struggle for existence.

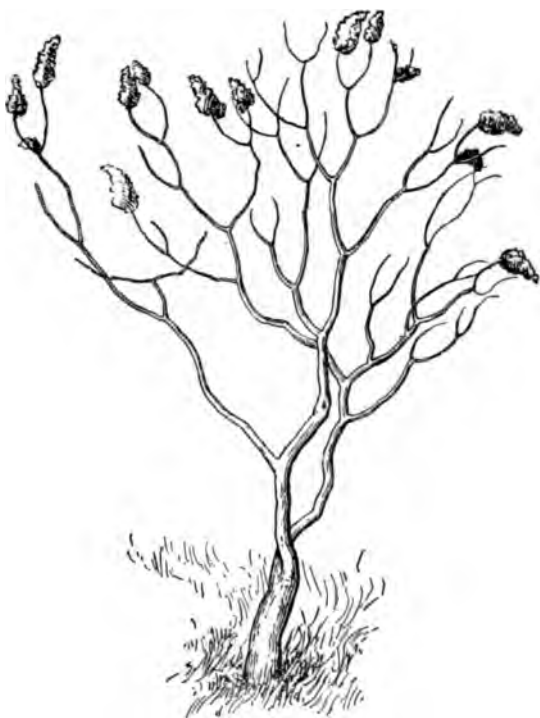


FIG. 11.

The forking growth of a sumac bush.

15. The pupil should now examine the grape-vine, and thoroughly master its method of branching. He will find that the trunk is not formed by continuous growth from a terminal bud, but from lateral buds. That is, the continued progress in stature is made by successive lateral branches or secondary leaders, each of which has been a leader in its turn. This is a type of diffuse branching, in distinction to that of those plants which grow constantly onward from the terminal bud, in a strict or straight fashion, of which the firs are typical examples. The pupil will now observe the method of branching of the various trees and shrubs which he meets, and determine which ones retain the leader throughout life. He will also be interested in the dry stalks of herbs, as mulleins and thistles, which stand in the waste places all winter. He will find that most trees are at first strict and afterward diffuse. Continued growth of the leader results in indeterminate or excurrent forms of trees, while the diffuse method results in determinate or deliquescent tree tops, like those of the elms and apple trees.

SUGGESTIONS. — The pupil should now explain why and when the common trees change from the strict to the diffuse style of branching; and he should endeavor to figure out the exact year in which the terminal bud was lost in certain small

trees which he may meet. The horse chestnut will be found interesting.

IV. THE STRUGGLE FOR EXISTENCE IN A TREE TOP

16. We have seen, in all the foregoing examples, that every twig bears more buds than can hope to find a chance to grow. Fig. 12 is an



FIG. 12.

The suppression of interior buds.

oak branch. It is seen that all the leaves are borne upon the very tips of the branches. That is, the interior of the space is poorly supplied with foliage. If the leaves are all borne at the ends

of the branches, then the branches must all arise from the ends the following year, for we have already found (2) that branches normally start only



FIG. 13.

The lengthening leaf-stalks on a horizontal shoot of Norway maple.

from leaf axils. The persisting branches, therefore, may mark the general lengths of the previous annual growths.

17. Following the branches back we notice that there are regular blank spaces and regular points of branching. Every space between the branches is a year's growth, but these spaces still show the buds which failed to grow. Even on the oldest part of the branch, the rough eleva-

tions where the buds were are still prominent; and these scars may often be found on branches many years old. The conclusion is that the method of branching of a tree depends more upon the position of the buds with reference to light than it does upon the position with reference to their arrangement upon the twig.

18. Let the pupil lie under a dense shade tree on a summer's day and look up into the dark top. He will find that the interior of the top is poorly supplied with leaves, and that the long branches are leafy at the ends. The outside of the top presents a wall of foliage, often so well thatched as to shed the rain like a roof, but the inside is comparatively bare. The tree may be a maple. Fig. 13



FIG. 14.

Tip shoot of Norway maple.

is the tip of a side shoot. The lower leaves have stretched out their stalks in eagerness for the sunlight, for the newer leaves are constantly

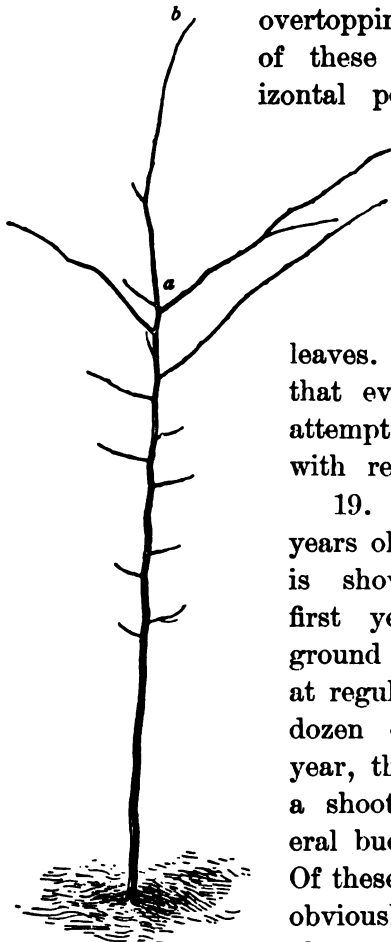


FIG. 15.

The curious history of a
wild cherry tree.

overtopping them; and the blades of these leaves stand in a horizontal position. Fig. 14 is a shoot from a topmost bough, where there is less struggle for light, and therefore shorter leaf-stalks and more various positions of leaves. It may be said, then, that even the leaves on a tree attempt to arrange themselves with reference to sunlight.

19. A black cherry tree two years old, taken from the woods, is shown in Fig. 15. The first year it grew from the ground to *a*, and it bore buds at regular intervals,—about two dozen of them. The second year, the terminal bud sent out a shoot to *b*, and thirteen lateral buds gave rise to branches. Of these thirteen lateral branches, obviously only three stand any chance of living in the dense shade of the forest. In fact, four or five of the lowest

twigs were dead when the picture was made; showing that the struggle for existence does not always result from competition among fellows but may arise from the crowding of other plants.

20. These three strong branches are less than four feet from the ground, but other old cherry trees standing near it had no branches within fifteen and twenty feet of the ground. They no doubt branched low down, as this one, but the branches eventually died in the struggle; and we therefore have reason to conclude that of all the branches on this little tree, only the terminal one, *b*, can long survive. The trunk of a tree, then, is the remainder in a long problem of subtraction.



FIG. 16.

Indeterminate habit of the sweet cherry.

SUGGESTIONS.—A young tree of the sweet garden cherry is shown in Fig. 16, and one of the Morello or pie cherry in Fig. 17. In the former, the terminal growths are strong, and the leader, or central trunk, has persisted. The latter has long since lost its

leader, and the side growths are strong. Let the pupil now figure out how many buds have perished (or at least failed to make permanent branches) in each of these trees, if they are supposed to be seven years old. Any garden cherry tree will give him the

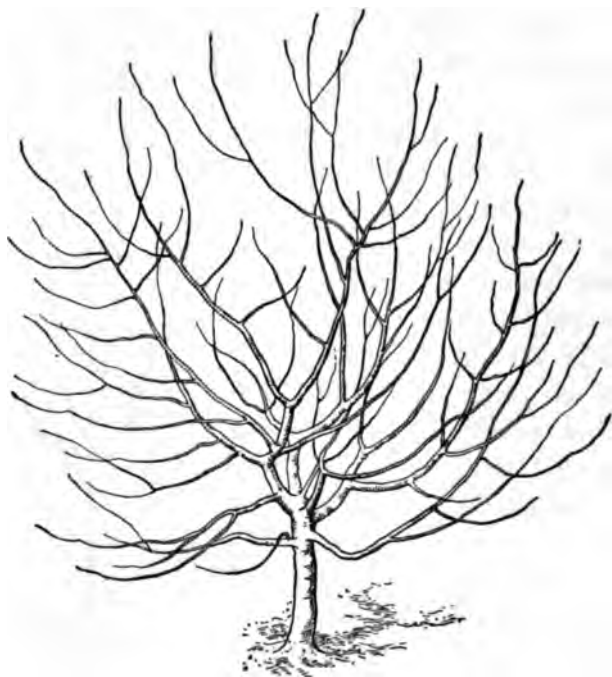


FIG. 17.

Determinate habit of the sour cherry.

probable number of buds to each annual growth. Even without the figures, it is evident that there are very many more failures than successes in any tree top. Let him also explain why the branches in Fig. 16 are in tiers.

V. KNOTS AND KNOT-HOLES

21. We have seen that some of the side branches upon the little cherry tree (Fig. 15) died, and that all the others will probably perish. Fig. 18



FIG. 18.

A dead branch and the mass of healing tissues at its base.



FIG. 19.

A knot-hole.

shows a dead limb on an oak tree. The limb became weak because the shade was too dense, and because the branches above it took more than their share of food. Finally, borers and fungi attacked it, and it died. It rotted slowly away, year by year its twigs fell, and finally a heavy

fall of snow broke it off as we now see it. As soon as it died, it became a menace to the tree, for the rot in its tissues might extend into the trunk. The tree made an effort to cover it up. The tissue piled higher and higher about its base,



FIG. 20.
Knot in a hemlock log.



FIG. 21.
Improper cutting of a limb.

reaching for the end of the wound. The limb was eaten away by decay, and became smaller and smaller in diameter, leaving a cup-like ring about its base. Finally it broke off, and a knot-hole was left. Such a knot-hole is seen in Fig. 19. Knot-holes on the bodies of trees, then, are the cavities left by dead and decaying limbs.

22. A hemlock log, split lengthwise, is drawn in Fig. 20. A knot extends to the center. This knot is the remains of a limb, and is nearly as old as the trunk, because it starts from the very center; that is, the limb sprung off when the tree was a mere sapling. The probability is that it is just one year younger than the trunk, for we have seen (6) that branches start only on the second year's wood, unless some stress of circumstances starts out the older and dormant buds. The limb finally died and broke off, and the stub was buried. The tissue has now grown out to the end of the stub, and nothing remains but to close over the hole. If the limb had rotted away, a squirrel or a woodpecker might have taken up his quarters in the cavity. The woodchopper, however, found only a knot; and a board sawed from the log would have had a knot whenever the saw cut across the old stub. If the knot were loose, it would fall out, and the board would have had a knot-hole. Knots and knot-holes in boards, therefore,



FIG. 22.

Proper cutting of a branch.

represent cross-sections of branches; and each one is the record of an event in the history of the tree.

23. A limb was sawn from a tree. Several years afterwards a drawing was made of the stub (Fig. 21). The limb had not yet healed in. The reason is apparent: the stub had been left so long that the tissue had not yet been able to pile up over it, and, having no life in itself, the branch could not make healing tissue of its own. The stub is now a monument to the man who pruned the tree. Fig. 22 shows how another limb was cut, and although the wound is not nearly so old as the other, it is being rapidly closed in. There are most important practical lessons, then, to be learned from the study of knot-holes,—two of which are that nature is a most heroic pruner, and that limbs must be sawn off close to the parent branch if the wounds are to heal well.

SUGGESTIONS.—The pupil should determine whether cross-sections of large branches (as in Figs. 21 and 22) really ever heal up (as wounds heal in human flesh), or whether they are simply hermetically sealed by a covering of tissue which arises from the sides of the wounds. In other words, does the end of the stub or wound ever become vitally connected with the healing tissue, or does this old wood remain lifeless and inert under the healing tissue as some foreign body (as a nail) might? Let the pupil procure a healed-over wound and split it lengthwise, and then answer these questions. The student should also observe the healing of wounds upon street trees and in orchards as related to the length at which the stub is left. Examine the knots in the floor and the wood-work.

The pupil should also explore the wood-pile, where he may now find much to interest him.

VI. THE FRUIT-SPUR

24. We have found (Figs. 3, 4, 5) that there are two kinds of buds, the leaf-buds, and the fruit-buds (or flower-buds). Some of these fruit-buds on the apple tree terminate short branches (*e e g*, Fig. 3), but now and then one is borne on the end of the axial shoot of the season (*c e*, Figs. 4 and 5). The latter is

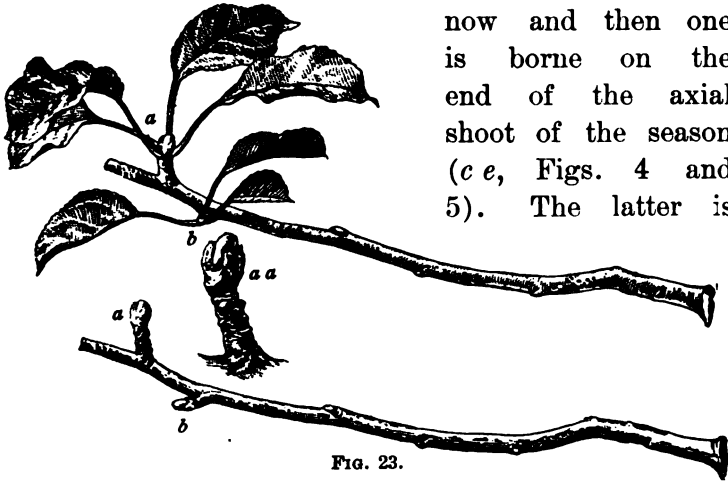


FIG. 23.

The fruit-spur and leaf-spur.

the exception in apple trees. Fig. 23 is an apple twig. Several dormant buds are seen on the lower part. At *a* and *b* are short branches. The branch *b* has made a small and pointed

bud, which is evidently to bear leaves only next year, while the stronger branch (*a*) has made a thick and rounded bud, which is to bear flowers. This fruit-bud is shown natural size at *a a*. The short lateral branches are called spurs, in distinction from the longer axial growths. We have already seen (8) that checking growth induces

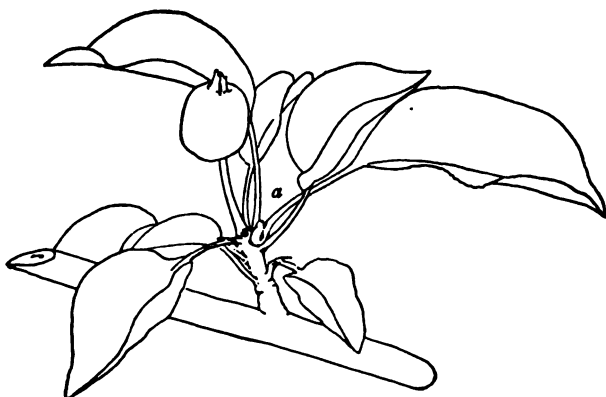


FIG. 24.

Formation of the lateral bud on the fruit-spur

fruitfulness, but on the other hand, starving or greatly weakening the growth generally gives only a weak leaf-bud.

25. When fruits or flowers are borne on the end of a spur, the direction of the growth is deflected, as we have seen (Obs. iii.). Fig. 24 is a bearing spur of apple. While the apple is grow-

ing from the terminal bud, a lateral bud (*a*) is forming to continue the spur the next year.

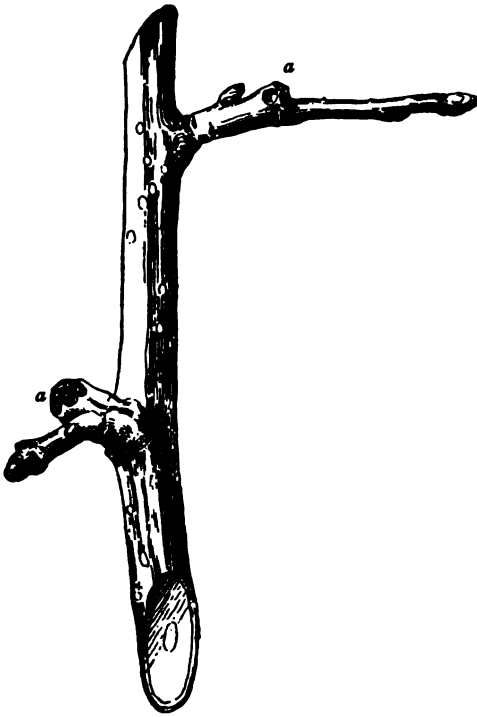


FIG. 25.

Spurs of a crab apple.

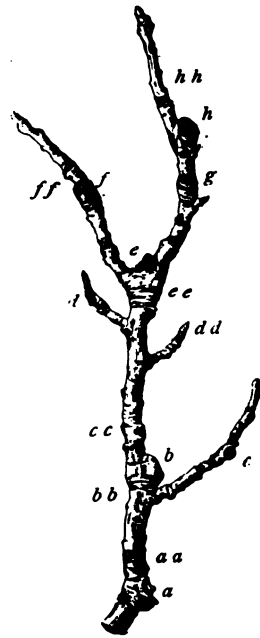


FIG. 26

Old spur of pear.

This is, therefore, a leaf-bud, for it must be the means of continuing the growth of the spur, and it is not likely to get nourishment enough,—

seeing that the apple is the chief concern,—to enable it to develop into a blossom-bud. There is, therefore, a necessary alternation of fruit-bearing buds and non-fruit-bearing buds in the spur of an apple tree.

26. A twig of Siberian crab apple, taken in spring, is shown in Fig. 25. Year before last, each of the spurs developed a fruit-bud at its summit, and last year each of these spurs bore flowers. The proof of this is seen in the scars left by the flower stems at *a a*. None of these flowers developed into ripe fruits, otherwise some of the scars would have been much larger than they are. It was probably for that very reason,—the failure of the fruit,—that the spurs were able to throw out leafy shoots nearly or quite an inch long, to continue the growth. Yet, even then, no fruit-bud developed on the ends of these spurs, for the small pointed ends clearly indicate leaf-buds. It is seen, therefore, that there may be an alternation in the fruit-spur, even when the spur does not bear fruit.

27. An old fruit-spur of a pear tree often looks like that in Fig. 26. One year it grew from the base to *a*, and there formed a fruit-bud. Let us suppose that this year was 1880. In 1881 a pear matured from this bud, as may be seen by a large scar at *a*. In this year, also, a lat-

eral bud developed. In 1882, this bud gave rise to a shoot. The "rings" whence it started are plainly seen at *a a*. It is noticeable, also, that the spur ceased to grow in the direction *a*. In this year 1882, the shoot grew to the rings *b b*, and there developed a fruit-bud. In 1883, this fruit-bud opened and produced flowers, one of which bore fruit, as shown by the large scar (*b*). The short growth from *b b* to *b* is that which took place in the elongation from the bud in this spring of 1883. While this fruit was developing, a leaf-spur pushed out from just below the fruit (*b*), and grew to the next series of rings (*c c*). A weaker bud also developed, which in 1884 pushed toward *c*. The six years' growths can be traced on this side shoot, and it once made a flower-bud, and a fruit set at *c*; but the small size of the scar shows that the fruit never attained maturity. It probably fell in very early summer. It is apparent that there is an alternation in the fruit-bearing of the pear, as in that of the apple; from this we may infer that there is something like an alternation of effort, or division of labor, in the successive growths of many plants.

28. The further history of this interesting pear spur may be summarized as follows: 1884, the barren shoot grew to *e e*, and made a fruit-bud; 1885, pear borne and carried to maturity at *e*,

two side buds developing, and also two weaker spurs at *d* and *dd*,—giving four chances of continuing the growth of the main spur; 1886, the spurs *d* and *dd* remained small and slender, but one of the upper branches grew on to *g* and there made a fruit-bud, while its twin bud (upon the left) did not elongate; 1887, fruit borne at *g*, but it did not mature (as shown by the small size of the scar), and the spur continued to *h*, and there made another fruit-bud; the twin bud now pushed on to *f* and made a fruit-bud, and the spurs *d* and *dd* are alive but evidently doomed soon to perish; 1888, fruits were borne at *f* and *h* (the bearing year having been changed), but neither of them matured, the side spurs pushed on to *ff* and *hh*, and an attempt was made at fruit-bearing at *d*; 1889, all shoots elongated and all end in leaf-buds, showing that the change in the bearing year had interfered with the normal development, for this should have been the year of fruit. Our spur, therefore, is ten years old; it has borne good fruits three times, and has made five unsuccessful attempts at fruit-bearing; some of the branches are too weak for further usefulness; and dormant buds still remain on the old wood near its base. From all of these observations, we are warranted in concluding that every crooked and knotty branch has a his-

tory which may be clearly deciphered by the observer from its own records.

29. A spur from a plum tree is shown in Fig. 27. Let the pupil trace its history. If we begin with the tip of the shoot, we determine that last year's growth began at *c*, the previous year's at *b*, and the preceding year's at *a*. The lower side spur has grown to *a a*, then to *b b*, then to the end. It will be seen that the buds and side spurs are borne usually near the ends of the growths, but the many scars show that buds were once present on the lower or older parts, but have perished in the struggle for existence. The spur differs greatly from that of the pear, in the fact that the buds are in twos or threes rather than single. It is difficult to distinguish which are leaf-buds and which fruit-buds. The character of the buds is to be determined from their positions rather than from their shapes. The first point to notice in de-



FIG. 27.

Fruit-spur of plum.

termining which are leaf-buds and which fruit-buds is the direction of growth of the entire spur. The pear spur is crooked and forked because the fruit-buds are terminal; if, therefore, the plum spur is straight or continuous in growth, it is because the terminal buds are leaf-buds. The side buds may therefore be inferred to be fruit-buds. Let the pupil examine a plum tree in either flower or fruit for further light upon this point, and from all his observations he will probably be able to satisfy himself that there are at least two distinct types of spurs upon fruit trees,—those of indeterminate growth (or terminal fruit-buds), and those of determinate growth (or terminal leaf-buds).

SUGGESTIONS.—The pupils should spend at least one lesson upon the fruit-spurs of the apple, and others upon those of the pear and plum. Each pupil should be asked to bring in the oldest and the youngest spurs which he can find. It may be well to suggest that there may be characteristic differences in the spurs (and also in the shapes and sizes of the fruit-buds) in different varieties of the pear. Then examine the fruit-bearing of any wild tree.

VII. FRUIT-BEARING, CONCLUDED

30. We have now seen how completely the records of the events in the life of a branch are preserved in its buds, scars, and method of growth. Fig. 28 is a twig cut from a peach tree in the

spring (or winter). It is two seasons old, as shown by the ring at *a*, and by the different buds upon the two portions. Upon the older portions there are dormant buds; there are also curious angular bodies at *eee*. We understand what the dormant buds mean, but the other bodies demand explanation. They are not growing branches, because they have no buds. The truncate ends are scars. These cannot be leaf-scars, because no buds are left above them (and we have found that buds grow in the axils of leaves). They must, then, be fruit-scars (or flower-scars). In other words, normal scars without the presence of buds indicate that a flower was borne at that point.

31. If we could have seen this twig (below *a*) in the spring of last year, a piece of it would have looked like Fig. 29. Three buds are borne together, the two lateral ones (which are evidently fruit-buds) being large and thick. If it were the habit of the peach to bear three leaf-buds together, the method of branching of the peach tree would tend to be by threes, but we know that this is not the fact. We know that these objects *a a* are not spurs (or branches), because the leaf-scar is visible below



FIG. 28.
Twig from
a peach
tree.

each one. That is, they are normal buds formed the previous year in the axils of leaves. If we could go back to this previous year, we should find the condition shown in Fig. 30, in which a triplet of leaves is making this group of buds ;



FIG 29

Triple buds of the peach.



FIG. 30.

The formation of the triple buds.

but there are other leaves borne singly, and in the axils of these only leaf-buds are borne (as a rule). From this it is seen that the method of fruit-bearing of the peach is very different from that of the apple, pear, and plum.

32. It must now be determined why the fruit-



FIG. 32.

Gooseberry
shoot.

scars are single in the twig in Fig. 28, while the fruit-buds are in pairs (with a leaf-bud between them) in the first place (Figs. 30, 29). Fig. 31 shows a half-grown peach which has arisen from one of the buds. A flower was produced from each bud, but in the struggle for existence one of them (and also the leaf-bud) perished. The twig in Fig. 28 has no buds upon the bodies which bore the peaches; therefore, these bodies are not leaf-bearing branches (or spurs), and they do not bear again. We have seen (Figs. 30, 29) that these fruit-buds are formed upon the axial growth of the current year, and bear the next year. It is, plain therefore, that the peach-grower should always aim to so manage his trees as to have a liberal supply of new growths.



FIG. 31.

Partly grown peach.

33. A gooseberry shoot is shown in Fig. 32. It is plain that the portion

from *a* to *b* grew the last season, and the portion below *a* two seasons ago. The upper portion has simple buds, while the lower portion has what appear to be elongated buds, but which are really fruit-spurs (for we have found that when buds elongate they become branches). Each of these spurs, then, bore a cluster of leaves last

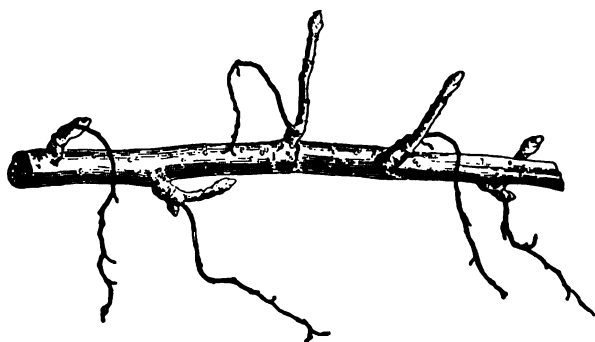


FIG. 33.

Fruit-bearing of the black currant.

year, as if it had been an apple spur. Let the pupil examine currant and gooseberry bushes (at any time of the year), and he will readily conclude that they bear fruits usually on spurs, but that these spurs generally bear only two or three times. Examine the barberry.

34. The two-year-old twig of a black currant is drawn in Fig. 33. It was taken in spring, and yet the remains of the old fruit-stems persist.

The point of attachment of these stems shows the lengths of the spurs of the year before, and the crook in the spur at that point shows that the fruit-bud was terminal (as it must be in Fig. 32, since the spur contains but a single bud), also that the subsequent growth of the spur arose from

a side bud. In fact, two of the spurs developed two side buds, only one of which, however, made a conspicuous growth.

Our conclusion, from observation suggested by the pictures, may be that each kind of plant has a system of fruit-bearing peculiar to itself, and that this system can usually be made out at any time of the year, if the plant has arrived at bearing age.



FIG. 34.

Bearing shoot of dwarf juneberry.

SUGGESTIONS.—Let the pupil now examine currant spurs, and determine whether there is an alternation of fruit-bearing in them, as there is in the apple and pear. Let him also study the dwarf juneberry (or else the common juneberry or shad-bush,) for similar problems of fruit-bearing (Fig. 34). Any fruit-bearing bush or tree, in the garden or the wild, may now be laid under tribute to add to the pupil's knowledge of fruit-spurs. A special effort

should be made to determine how many years the spur maintains sufficient vigor to bear good fruit.

VIII. CHARACTERS IN WINTER TWIGS

35. A twig of the balm of Gilead is shown in Fig. 35. There are several conspicuous features on it: the great prominence of some buds and the smallness of others (the result of struggle for place and light); the striking shape of the buds; the very large scars where the leaf-stalks were attached. The marks or dots on these scars are places where the woody bundles of the leaf-stalk were attached to the twig. Some of the axils developed no buds; and it is interesting to note that these failures took place at the base and top of the twig. The pupil should observe the greater development of buds in the middle of the twig. We should expect the variation in the size of the buds to be an incidental feature,—varying in different twigs. The size, shape and color of the buds, the shape of the bud-scales, and the peculiarities of the



FIG. 35.
*Twig of balm
of Gilead.*

leaf-scars are characteristic marks in plants, and enable us to tell one kind from another, the same as the characters of leaves and flowers do.



FIG. 36.

Twig of Japan
walnut.

36. Let the pupil procure twigs of some of the walnuts (as the black walnut and butternut), and observe the curious scars and other characters. Fig. 36 is a tip of a shoot of the Japan walnut (now coming to be cultivated). The scars are most peculiar. A striking thing about this twig is the fact that there are more buds than axils; that is, there are two or three buds to each axil, and two well-developed terminal buds. Perhaps these accessory or supernumerary buds explain some peculiarities in the branching of the walnut, and perhaps the extra buds simply perish in the struggle for existence, and exert no permanent effect upon the tree;



FIG. 37.

Leaf-scar of
sumac.

the pupil must find out. He may also examine the Tartarian honeysuckle, honey locust, and other

common plants for accessory buds; he will find that in some plants they are superposed (one over the other), and in others they are collateral (or side by side). At all events, it is certain that some plants produce more buds than leaves.

37. The leaf-scar of the common sumac (Fig. 37), the plane tree (often called sycamore and buttonwood), the common locust, and a few other plants, encircles the bud. If one were to examine the twig the previous season, he would find that the bud is concealed within the hollowed base of the leaf-stalk. Such buds may be said to be calyptrate (covered with a hood).

38. A bit of an old dahlia stalk is shown in Fig. 38. The leaf-scars are prominent, in the form of a ring (for the leaves are borne on opposite sides of the stem, and the bases of the stalks are much dilated). Fig. 39 is a stem

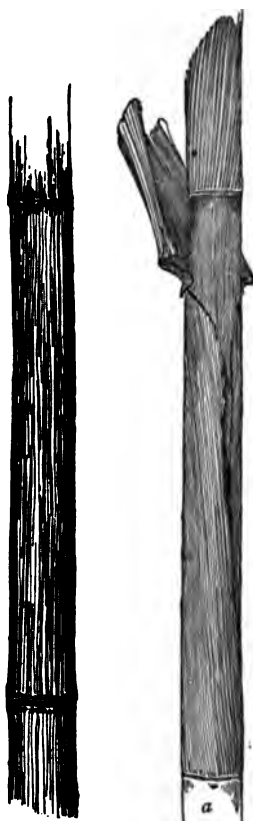


FIG. 38.

Leaf-scars
of dahlia.

FIG. 39.

Leaf attach-
ment of a reed.

of a large reed or grass (*arundo*). In this case the leaf has not fallen away at a joint, leaving a scar, but has been torn in two by the wind. The point of attachment of the leaf is at the lower end of the sheath (*a*). Sometimes the withered leaf-stalk of the dahlia adheres to the stem all winter, but this is because the plant was killed by frost before the leaves had reached full maturity. These old leaf-stalks are easily pulled away, when a distinct scar (as in Fig. 38) is left,



FIG. 40.

Leaf attachment of green-briar.



FIG. 41.

Leaf attachment of cabbage palmetto.

but the leaves of the reed do not separate so definitely; they are torn away if one pulls them from the plant. There are, then, two unlike methods of casting the foliage,—the clean-cut or articular way, and the non-articular way.

39. A joint of the common wild smilax or

green-briar is seen in Fig. 40, and upon this the base of the old leaf-stalk still remains (*a*). That is, the leaf did not fall by separating from the trunk, but by the breaking of its stalk. This curious behaviour of the smilax will suggest the palmetto to those who live in the south. Fig. 41 shows a portion of the crown of one of these palms. It is seen that the leaves have broken

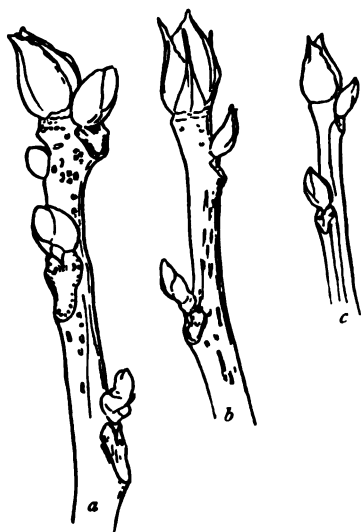


FIG. 42.

Twigs of three hickories.

midway of the stalks, and the old bases still remain. After a time, these bases split and the halves spread apart, giving the tree a peculiar criss-cross appearance; and finally they loosen and fall, exposing the smaller cylinder of the hard trunk.

39a. The pupil should now examine the methods of leaf-casting in all the plants which he meets. The articular method will be found to be the rule in all common trees and bushes in the north, and in such herbs as pigweeds, hollyhocks, the mints (like catnip), golden-rod, aster, and the like. The non-articular way will be found, as a rule, in the palms, green-briars, sedges, lilies, cannas, grasses, Indian corn and cereal grains, and so on. We shall subsequently find that these plants represent two great groups of the

vegetable kingdom. Examine the oaks and beeches, and other trees which hold dead leaves during the winter. Is this due to non-articular leaf-casting, or merely to the firmness of attachment to the plant? Do these old leaves fall as soon as the twig begins to swell in the spring, or do they hang year after year, until torn off by the elements?

40. It has been said (35) that the features of winter twigs are characteristic of the different kinds of plants. Now let the pupil collect the twigs of apple and pear, different kinds of

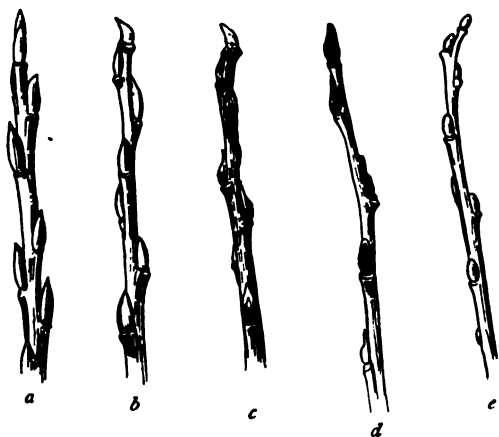


FIG. 43.

Twigs of various willows.

maples, currants and gooseberries, various oaks, or any other closely related plants which grow in his neighborhood, and then compare the one with the other. This done, let him collect indiscriminately of any plants he meets, and then sort the twigs into similar kinds. He will soon discover that plants have characteristic marks or features in winter as well as in summer.

40a. Some of the kinds of difference which the pupil may expect to find are shown in the pictures. In Fig. 42, *a* is the

small-fruited hickory, *b* the common white or shag-bark, and *c* the pignut hickory. Even in such similar plants as the different kinds of bushy willows, there are differences in the leafless twigs. In Fig. 43, *a* is the heart-leaved willow, with long, cylindrical and pointed buds; *b* is one form of another (upland) willow, with flat and light brown buds; *c* is a form of the same, with narrower and more appressed, fuzzy buds and less prominent leaf-scars; *d* and *e* are two forms of the common glaucous willow, the former having flat buds and the latter smaller and rounder buds. (The twigs in Fig. 42 are: *a*, *Hicoria microcarpa*; *b*, *Hicoria ovata*, or *Carya alba*; *c*, *Hicoria glabra*, or *Carya porcina*. The specimens in Fig. 43 are: *a*, *Salix cordata*, staminate; *b*, *Salix rostrata*, staminate; *c*, *Salix rostrata*, pistillate; *d*, *Salix discolor*, staminate; *e*, *Salix discolor*, pistillate.)

IX. THE OPENING OF THE BUDS

41. We are curious to know how the buds of the apple twigs (Figs. 1, 3 and 4) open in the spring, and how the young growths start out. Let us look at the trees, and see. Fig. 44 is from the same Siberian crab-apple tree that Fig. 25 is. The pupil will see where the fruit was borne last year. He will see at a glance that the present opening buds are the leaf-buds which were formed on the side of the spur last year. The little dry scales which covered the buds in the winter have been pushed aside, and a new shoot is coming forth. The leaves are many. In a few days we shall be able to count them. Already nine of them are visible on the upper spur,

and only eleven were borne all summer long on the annual growth in Fig. 2. The fact is that there are as many leaves packed away in the bud (as a rule) as there will be leaves on next year's shoot.

42. Another most curious fact about these opening buds is that the lowest leaves are smaller than the middle ones. The full size of the enfolded leaves cannot yet be made out. Let the pupil see to what size they will attain. It is enough to know that the lowest are smallest and presumably weakest; and Fig. 2 shows that they are borne closer



FIG. 44.

Opening buds of a crab-apple.

together. We have also seen, in all our specimens, that very few good buds are borne at the base of the annual growth (compare Fig. 35). We suspect, therefore, that not only the number of leaves, but the character of the forthcoming buds, is very largely determined beforehand.

43. These buds open with surprising quickness when spring comes (particularly at the north). The buds have been entirely inactive all winter, so far as we could see; and, moreover, they are just the same shape and size in the spring as they were when the leaves dropped in the fall. We must conclude, then, that these leaves and an embryo shoot were packed away in the bud during the growing season of last year; and this is true.

44. The pupil can still further satisfy himself of the truth of this conclusion by taking into the house during the winter a twig from a tree or bush, and keeping it in water in a warm room. In a few weeks, it will produce leaves, and also flowers, if it bears flower-buds. This experiment also shows that the first leaves and flowers which come out on early spring-flowering trees and bushes are sustained by nourishment which is stored up in the branch or the bud, not by that taken in at the time by the roots.

45. Let the pupil examine a rapidly-growing shoot of any plant in spring or very early summer. He will not find the large buds which he sees in fall and winter. He concludes, therefore, that the plant does not need these large buds for purposes of growth. Plants must have a means of carrying the growing points over winter (or over the dry or inactive season, in the tropics); and in

order that time may be gained, the future branch is packed away in miniature, ready to leap forth upon the first awakening of spring.

46. If the leaves—and therefore the number of buds on the shoot—are determined in the bud, how does the shoot increase in length? If it grows from its tip alone, the leaves would be left behind. We know that this is not the case. Again, we know that the joints or nodes (the places where the leaves are borne) are really much closer together in these opening shoots in Fig. 44 than they are in the mature shoots in Figs. 1 and 2. In other



FIG. 45.

Opening of leaf-buds and flower-buds.

words, it is plain that the shoot increases in length by elongating the internodes (or spaces between the buds)

47. Another apple twig is shown in Fig. 45. We are already familiar with the leaf-buds, but the lowest bud is strange. It is a fruit-bud. The bud-scales fall away, as before, but there comes forth

not only a cluster of leaves but a cluster of unopened flowers. We know that when an apple is borne upon a spur, the spur ceases to grow in that direction (10); that is, the apple fruit is terminal. Then we know that the shoot from this bud is destined to remain short all summer, and we infer that the leaves upon this short spur will exercise an important office in nourishing the fruit.

SUGGESTIONS.—The pupil should prove the conclusion in 46 experimentally. Let him lay off spaces at equal distances (say one-quarter inch) on a young growing twig, and mark them with indelible ink. If he visits the twig from day to day, and takes exact measurements, he will make an interesting discovery.

X. THE OPENING OF THE BUDS, CONTINUED

48. We know that apples are usually borne singly, and yet the flowers (as seen in Fig. 45) are in clusters. Two or three weeks after the flowers have gone, we examine the young apples, and we see something like Fig. 46. One apple has persisted and all the others have perished. There is, then, struggle for existence even among flowers; and in apples, at least, we are to expect many more flowers than fruits.

49. A bit of apricot branch is shown in Fig. 47. It has four fruit-buds. The scales of the buds are seen at the base of each flower,—pushed

apart by the bursting growth. But in this plant only one flower comes from a bud, and there are no leaves. This is like the peach (Figs. 28, 31). These buds, then, are fruit-buds only. That is, there are at least two kinds of fruit-buds, the true



FIG. 46.

Struggle for existence among the apple flowers.



FIG. 47.

Fruiting branch of apricot.

or simple fruit-buds (like those of the apricot and peach), and the mixed fruit-buds (as in the apple, pear and cherry)

50. If we were to examine a fruit-bud of the apricot (or peach) just as it begins to swell in spring, we could easily see the flower within. If the bud were cut lengthwise with a sharp knife



FIG. 48.

Bud of apricot
in longitudinal
section.

parts are all present before it begins to swell. The parts are rather small for unblown flower, but that

led or tucked away in an unexpected

51. An opening pear bud is seen is evident that it is a leaf-bud.

wholly unlike the expanding apple (Fig. 44), however. It is long and slender, and curiously marked. Let the oil watch the pear buds as they open will observe that these outer bodies the bud-scales, and that they soon fall off. These scales have actually grown to their former dimensions are indicated by their brown tips. It was these tips

which are the first to appear.

maple (Fig. 50) shows the bud-scales (1, 2, 3, 4) greatly enlarging, and the arrangement of them is peculiar. These great green scales suggest leaves. Fig. 51 is a sprig of black currant. Here it is seen that some of the scales actually produce small leaf-blades on their tips. It is also noticeable that there is a gradual progression in size of leaves, as there is in the apple (Fig. 44). Now let the pupil examine the opening buds of the various plants which he meets, and he will soon come to the conclusion that bud-scales are only modified leaves. Or, to state the case more accurately, bud-scales and leaves are only different forms of one kind of plant member.

53. We have concluded that bud-scales are homologous with leaves because we have seen



FIG. 50.

Expanding shoot of Norway maple.



FIG. 51.

ing shoot of black currant.

buds, and, fore, to the (whether of or of flower spring from buds. Fig. 1 well known bud of the dendron. pupil has the tunity, he should examine the cluster of three or of one large-bud. He will find, springing from axil of each scale. He will

method,—that of homology, or the comparison with structures in other plants which give evidence of having had a similar origin.



FIG. 52.
Rhododendron flower-bud.

53a. Morphology (literally the science of forms) is used to denote the study of the different forms which any part assumes, and the relationships of parts or members of plants (and of animals) to each other. It inquires into the origin and method of development of a leaf or a root, and endeavors to determine how that part is related to other parts, and to an assumed ideal type.

53b. Homology is the consideration of the origin of parts with reference to each other. It implies genealogical relationship. Homologous parts or organs are those which have similar structural relations to a given or fundamental type, or those which have evidently had similar origins in the development of the plant or the animal.

53c. Analogy is similarity in function (or use), or adaptation, of any two parts, without reference to origin. It relates to superficial resemblances, while homology relates to fundamental or genetic relationships.



FIG. 53.

Flowering shoot of the quince.

ment in n
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bud-scales
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plant mem
scales are
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office of l
is, the sa
may be ad
erent uses.
must now c
himself wh
scales are
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discovering
office of
wood and

is, the axis has elongated considerably since the opening of the bud. A quince flower is drawn in Fig. 53. This, too, is borne upon a leafy shoot of the season. (The pupil should now explain why this shoot is said to be of the current season's growth.) Now let the pupil examine the flower-clusters and shoots of grapes, raspberries,

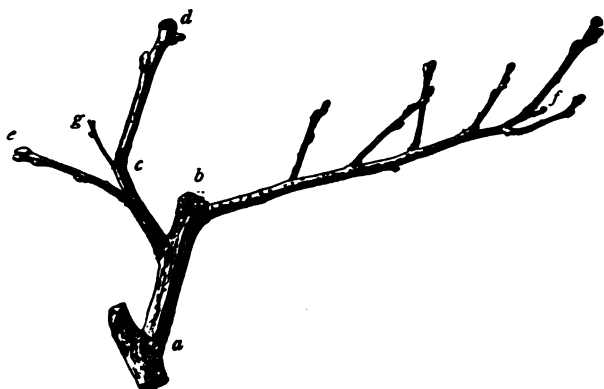


FIG. 54.

Twig of quince.

blackberries and walnuts. We have already found (49) that some fruit-buds are simple and others mixed. We now find that there is still a third class, those which may be called co-terminal, because they terminate the axial growth of the season, and thereby cause a diffuse or determinate growth of the plant.

56. We can now interpret the winter twigs of

er fruit was borne at *b*. While

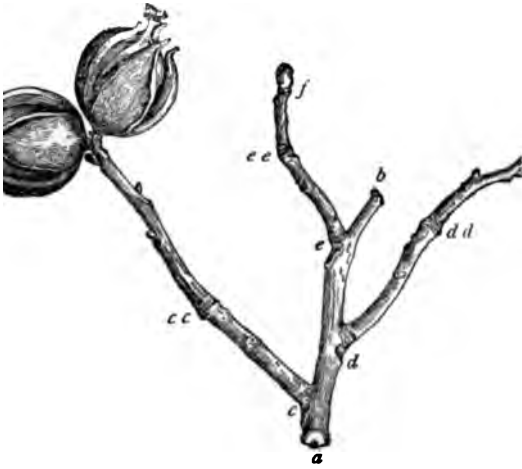


FIG. 55.

Branch of the small-fruited hickory.

was growing, side shoots started of
ions, one extending to *f* and the
During the following winter

for its tip also had died before the growing season began. How old, then, is the twig 54?

SUGGESTIONS.—Let the pupil also trace out the history of the hickory branch in Fig. 55. Fig. 160, may aid him. Let him explain if the zigzag and tortuous growth of any of the common trees and shrubs is in any way associated with this co-terminal type of fruit-bearing.

XI. THE OPENING OF THE BUDS, CONCLUDED

57. If we look again at the opening apple shoot in Fig. 45, we may notice the method of unrolling of the young leaves; for we have found (50) that the parts in the bud are not only very small, but curiously folded and packed away. The leaf *a* is seen to be unrolling outwards from above on each edge. In other words, the leaf was rolled inward on top from both sides, or was involute in the bud.

58. The expanding shoot of a common honeysuckle is seen in Fig. 56. The successive pairs of leaves are seen at *a a*, *b b*, *c c*. These leaves are all turned backward, or revolute. Coming to the very tip of the shoot, however (*d*), it is seen that the leaves are really involute at first. They become revolute soon after they open. In studying the manner in which the leaves are folded in the bud, therefore, it is important that the speci-



FIG. 56.

growing shoot of honeysuckle.



FIG. 57.

Conduplicate leaf

in our observation. Fig. 57 is a
 shoot of the peach. Here the halves
 are perfectly closed together, and
 they become trough-shaped, as in t



FIG. 58.

Leaf of blue
palmetto, un-
folding.

together sidewise, like the folds of a fan. The two halves of the leaves are really folded upon each other, however, in a conduplicate way, so that the packing away of this leaf represents two methods. Fig. 58 is an opening leaf of the blue palmetto of Florida. In this case, the leaf-blade is folded sidewise completely like the plaits of a fan. This method of folding is called the plaited or plicate manner.

61. An opening bud of the tulip tree (or white wood) is at Fig. 59. In this instance, the



FIG. 59.

Inflexed vernation of tulip tree.

leaf-blade is bent over upon the face of the stalk, or is inflexed (seen at *a*). In the horse-chestnut, however (Fig. 60), the leaf is bent down upon the back of the petiole, or is reflexed. In this case,



FIG. 60.

Vernation of horse-chestnut.

and a front view—showing some expanded—at *b*. This is a circular method of folding, and is not common to the ferns and their allies, although it is seen in the sundew.

We find, then, that there are various methods of folding the leaves of plants.

of the shoot, and the necessity of folding the parts of the shoot before, and after, the shoot has been folded. The same method of folding is seen in the entire shoot. 62. A is represented in Fig. 61. A view of the rolling of the shoot tip.

of the other, so that they may be said to be astride. If we examine the common white willow, however, we shall find that one leaf completely enfolds another. There are, then, two elements in this tucking away in the bud,—the particular manner in which each leaf is folded, and the way in which one leaf lies upon another. All these matters are among the most interesting phenomena of spring time, and it has, therefore, come about that this præfoliation or packing away of the leaves in the bud is called vernation (indirectly from the Latin word for spring). In the same way, the arrangement of the parts of the flower in the bud,—which follows the same forms as the leaves do,—is known as æstivation (indirectly from the Latin for summer).



FIG. 61.

Vernation of one of the cultivated ferns.

63a. Both the method of folding and the arrangement of the parts is commonly represented by a diagrammatic cross-section of the swelling buds. The great Linnæus defined the methods of vernation (or "foliation") by the diagrams which are reproduced in Fig. 62. The key is as follows: No. 1, convolute; 2, involute;

3, revolute [evidently meant to represent a leaf bottom side up];
4, conduplicate; 5, equitant [one leaf wholly enfolding another];

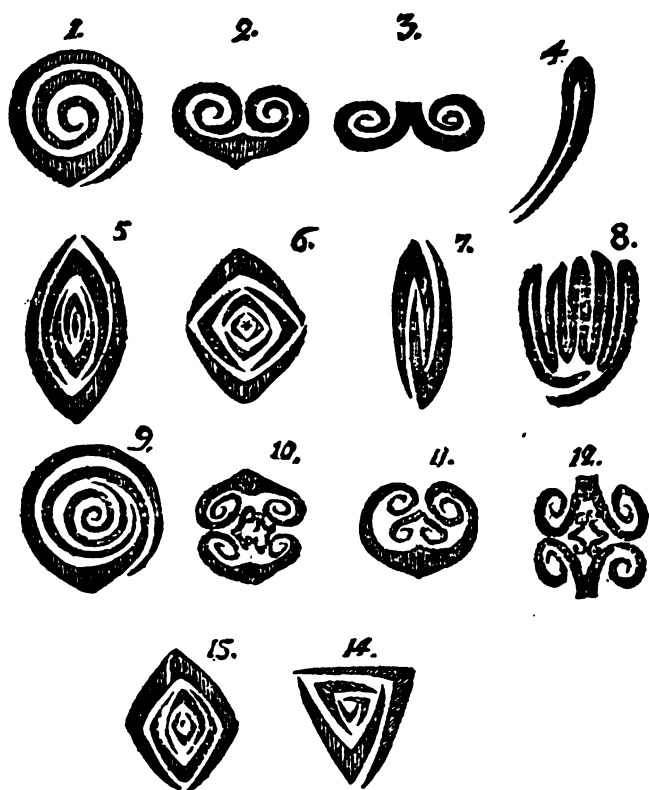


FIG. 62.

Diagrams of veneration given by Linnaeus. 1751.

imbricate [leaves at right angles in the different series]; 7, obvo-
lute [edges interlapping]; 8, plaited or plicate; 9, two convolute

leaves; 10, involute opposite leaves; 11, involute alternate leaves; 12, revolute opposite leaves; 13, equitant two-edged; 14, equitant three-sided. In writing of flowers, it is the custom of systematic botanists to describe them as valvate when the edges of the parts simply meet in the bud, and to call them imbricate when they distinctly overlap.

SUGGESTIONS.—The pupil should now examine the bursting buds of the plants which he meets. He will be interested to discover the almost infinite variation in method of vernalion, and he will see that this method does not always fall readily into the various categories which have been named and described. There are all kinds of intermediate methods. For an ill-defined, crumpled-plicate vernalion, examine the rhubarb. To show the small modifications in the same general method, examine the leaves (when just appearing) of the lilac and the peach, and observe the position of the leaf-edges. The general conclusion will be that some one method is fairly constant in each kind of plant, and is, therefore, characteristic of the plant.

XII. ARRANGEMENT OF THE BUDS

64. The honeysuckle shoot (Fig. 56) shows at a glance that the leaves are arranged in a definite order; and if there is an arrangement of leaves, there is also an arrangement of buds. In this case, the leaves are in pairs, one leaf exactly opposite the other upon the stem. Moreover, the pairs alternate in arrangement. That is, if one pair, *a a*, stands east and west, the succeeding pair, *b b*, stands north and south, and the third pair, *c c*, stands east and west again. The third pair is, therefore, perpendicularly over the

first pair, in a vertical shoot. A similar arrangement is suggested by the bud-scales of the Norway maple (Fig. 50), and also by the four expanding leaves of horse-chestnut (Fig. 60). The pupil must now examine all these plants, if he has

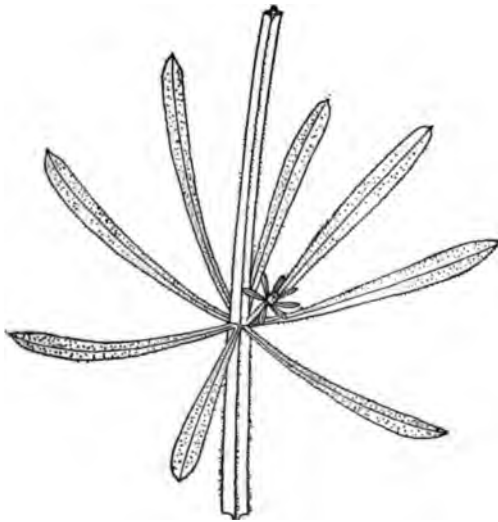


FIG. 63.

Whorled leaves of galium.

access to them, or their near relatives, and see if there is a definite arrangement of buds on the winter twigs. He will find plants, at all events, in which the buds are opposite each other. If the pairs are successively in the same position, or exactly over each other (which is rare), the buds will form two rows up and down

the stem. If they alternate (as in maple, horse-chestnut and honeysuckle), they make four rows, or are decussate.

65. A common galium or bedstraw is shown in Fig. 63. The plant (a low herb)—or some of its kin—is common in moist places and in woods.

Here the leaves are opposite, but there are commonly four pairs at each node (see 88 *a*), and there are several rows of leaves up and down the stem. Such leaves are whorled or verticillate (terms applied to opposite parts of more than one pair).

66. In most of the other shoots which we have seen, the buds are not opposite, but alternate. If all our conclusions in respect to vernalion are correct, however, it must follow that there is some method of arrangement of the alternate buds, for the enfolded leaves (in the axils of which buds are to develop) have definite positions with reference to each other. The effort of the leaves to expose themselves to sunlight may have exerted some influence in bringing about a definite arrangement of leaves, although it is doubtful if this has been the sole, or even the chief, cause.

67. Let the pupil secure a twig of elm, mulberry, basswood, a stalk of grass, or of Indian corn. Fig. 64 is an elm twig. The bud 3 is directly above 1, and 2 is half way between them. If this arrangement is true of the other buds, each bud must be 180 degrees from every other. The buds are therefore 2-ranked, and they are as far apart, in angular distance, as they can be placed. The pupil will now want to examine young, branchy growths of the elm, to see if the leafy sprays



FIG. 64.
Twig of
elm.

are flat because of this distichous (or two-sided) arrangement. This arrangement, then, in which the third bud is directly over the first, and in which the buds are half a circumference apart, may be represented by the fraction one-half. If we were to make a mark from 1 to 3, passing over 2, we should make one revolution of the stem, and this fact is expressed by the numerator of the fraction. We should also pass over two buds (counting the first, but not the last), and this fact is represented by the denominator.

68. All this suggests a new subject of inquiry. The pupil will now profit by an examination of any twig. If he desires to work out the mathematics of the cycles, let him secure straight growths, preferably from upward-growing branches, where light is equally diffused; but if he wishes to see things exactly as they are, let him take the first shoot which



FIG. 65.
Twig of plum.

comes to his hand, but note the conditions under which it grew. To begin with, he might try alders, and birches, and sedges. Here he will find the fourth leaf normally over the first. He can easily construct the numerical cycle.

69. Let us go back to the apple, or take up the plum (Fig. 65). Here 6 is over 1, and the mark passes twice about the stem. The angular distance between the buds, therefore, must be two-fifths of a circumference. We will cut the bark loose in a straight line from 1 to 6, and peel it off (Fig. 66). If the strip of bark were one inch wide, then each bud would be two-fifths of an inch at one side of the neighbors above and below it, if the branch were straight and symmetrical. Now turn back and see if the artist has correctly drawn Figs. 1, 3, 28, 35.

70. We have now found arrangements represented by the fractions one-half, one-third, two-fifths. The last fraction can be made by adding the numerators and denominators in the first two. Can we, then, add the last two and prophesy a

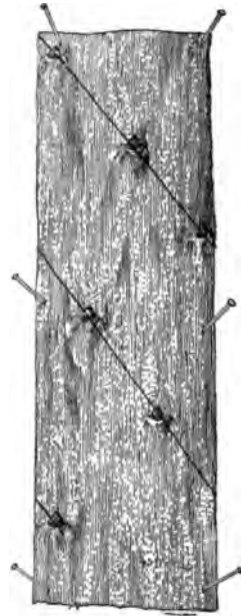


FIG. 66.

Showing the arrangement of the buds upon a plum twig.

three-eighths arrangement? Let the pupil examine osage orange, live-for-ever, holly, plantain, and find out. He may also examine the scales on the house-leek (or old-hen-and-chickens of the gardens), bud-scales, pine cones, scaly bulbs, leaves of palms, and of firs and pines. the seeds in a sunflower head, for other and more involved cycles. This arrangement of the parts is known as phyllotaxy, literally "leaf-arrangement," but it is generally more easily studied upon winter twigs than upon foliaceous shoots.

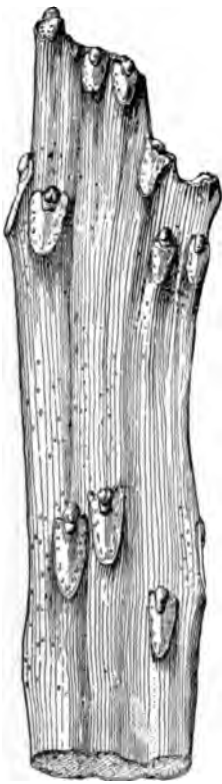


FIG. 67.

Fasciated branch of
ailanthus.

71. The ailanthus (or "tree of heaven") has a two-fifths phyllotaxy, like the apple, cherry, peach, plum, willow, and many other common trees (for this is the most frequent arrangement). Yet Fig. 67 is the tip of a branch of this tree. The pupil will see that the buds have no order. The branch is much flattened or fasciated. This fasciation or abnormal flattening is not rare, but is commonest in plants of comparatively soft tissue, and is usually associated with very vigorous growth. The point

is, in this connection, that nature is not always formal. There is no plant-form so rigid that it may not be broken or modified upon occasion. Neither is it true that the buds or leaves of all plants have a definite method of arrangement, although such is the rule. The pupil will be puzzled to work out cycles in the stems of many lilies, for example.

SUGGESTIONS.—In the study of phyllotaxy, it is not only important to work out the mathematical cycles, but also to discover deviations or variations from the rule. In other words, the pupil should examine any branches upon a tree rather than those only which best show the mathematical arrangement. He should endeavor to discover whether deviations are in any way associated with the position of the branch with respect to light. He will be interested in an endeavor to find a numerical arrangement of the eyes of an Irish potato.

XIII. EXPANSION OF THE BARK

72. The fasciated branch in Fig. 67 not only raises the question as to the cause of fasciation, but the more pertinent one as to why stems remain normally terete (or cylindrical). Consider for a moment the general make-up of the plant cylinder. The young shoot is tightly enveloped with bark. We observe that in many plants the increase in diameter of the stem comes about by the formation of rings of new tissue (or new

wood) under the bark, and we know that in all plants the growth in thickness takes place upon the inside of the cylinder, and not upon the very outside.



FIG. 68.

Cracking of the bark on an elm branch.



FIG. 69.

Piece of bark from an old elm trunk.

73. It is evident, then, that the covering of bark must expand in order to allow of the expansion of the woody cylinder within it. The tissues must, therefore, be under constant pressure or tension. It has been determined that the pressure within a growing trunk is often as much as fifty pounds to the square inch.

74. A piece of an elm branch ten years old is drawn in Fig. 68. It is an inch in diameter, yet the bark at the top is

smooth and intact. At one time, the shoot was not more than one-eighth of an inch in diameter at this point. The pupil may now figure out how much this bark has expanded by the combined action of intercalary growth and stretching.

75. The lower part of the limb shows that the outer layers of bark (which are long since dead, and act only as protective tissue) have reached the limit of their expanding capacity and have begun to split. The pupil will now be interested in the bark upon the body of an old elm tree (Fig. 69); and he should be able to suggest one reason why stems remain terete, and why the old bark becomes marked with furrows, scales and plates.

76. If, for any reason, the bark should become so dense and strong that the trunk cannot expand, the tree is said to be "bark-bound." Such condition is not rare in orchard trees which have been neglected. When good tillage is given to such trees, they may not be able to overcome the rigidity of the old bark, and, therefore, do not respond to the treatment. Sometimes the thinner-barked limbs may outgrow in diameter the trunk or the old branches below them. The remedy is to release the tension. This may be done either by softening the bark (by washes of soap or lye), or by separating it. The latter is done by slitting the bark-bound portion (in spring), thrusting the point of a knife through the bark to the wood and then drawing the blade down the entire length of the bark-bound portion. The slit is scarcely discernible at first, but it opens with the growth of the tree, filling up with new tissue beneath. Let the pupil

consider the ridges which he now and then finds upon trees, and determine if they have any significance.

77. The pupil should now turn to Fig. 22, and consider the ring of tissue which rolls out over the wound. This tissue in time covers the wound. It forms most rapidly and uniformly when the wound is smooth and regular. Observe the healing on broken and splintered limbs; also the difference in rapidity of healing between wounds on strong and weak limbs. There is difference in the rapidity of the healing process in different kinds of trees. Compare the apple tree and the pine. This tissue may in turn become bark-bound, and the healing may stop. On large wounds it progresses more rapidly the first few years than it does later. Could not the point of the knife-blade be used to relieve the pressure upon this callus (as the roll of healing tissue is called)?

SUGGESTIONS.—Are the trunks of trees ever perfectly cylindrical? If not, what may cause the irregularities? Do trunks often grow more on one side than the other? Slit a rapidly-growing limb, in spring, with a knife blade, and watch the result during the season. Consult the woodpile again, and observe the variations in thickness of the annual rings, and especially of the same ring at different places in the circumference. Cross-sections of horizontal branches are interesting in this connection. Note the enlargement at the base of a branch, and determine if this enlargement or bulge is larger on long, horizontal limbs than on upright ones. Why does this bulge develop? Does it serve as a brace to the limb, and is it developed as the result of constant strain?

XIV. A BIT OF HISTORY

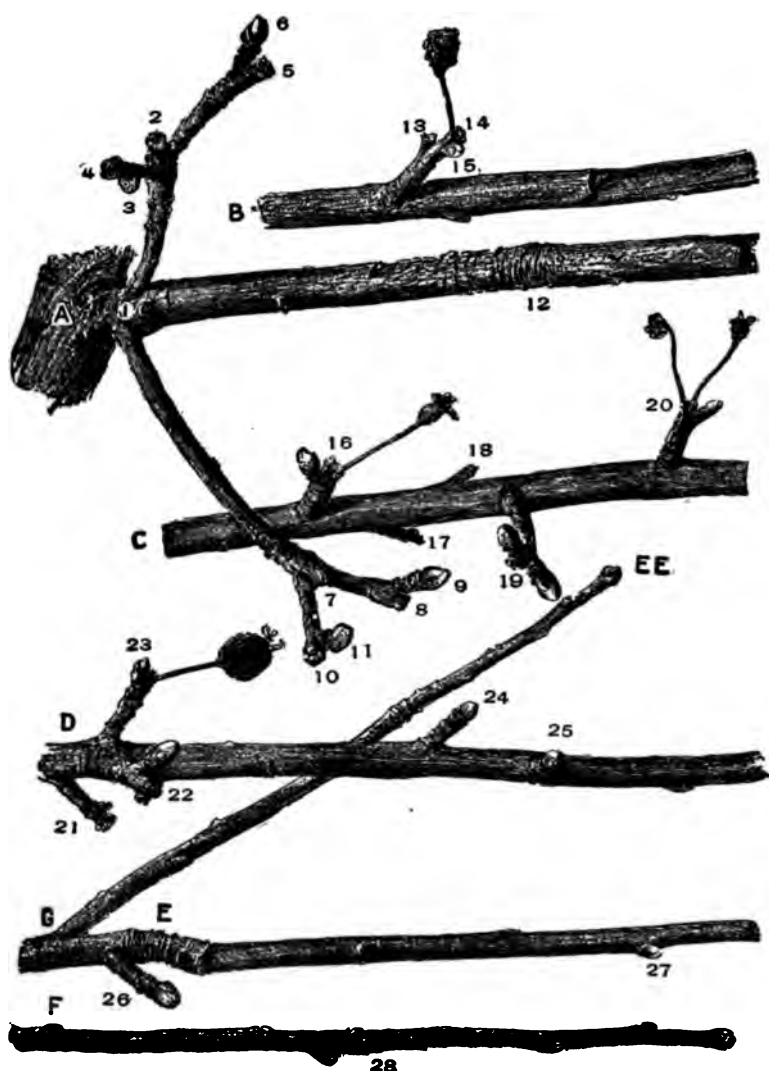
78. The apple shoot in Fig. 70 contains a volume of history. The illustration shows a single twig, but the branch is so long that it is broken several times in order to get it on the page. It arises at A, and continues, consecutively, at B, C, D, G, and F. A prominent feature of this shoot,—as, in fact, of almost any branch or plant,—is the presence of unlikenesses or dissimilarities. No two of the members are alike.

79. Let us count the yearly rings, and see how old the whole limb is. These rings are at 28, E, D, 12, 1,—five of them; and as the shoot grew one year before it made any ring, and another year made no increase in length—as we shall see presently—the whole branch must be seven years old. That is, the limb presumably started in 1890.

79a. It is really impossible to tell whether the shoot started from the limb A in 1889 or 1890, without knowing the age of A; for the spur may have developed its blossom bud at the end in either the first or the second year of its life. That is, young fruit-spurs sometimes make a blossom bud the very year they start, but they oftener "stand still" the second year, and delay the formation of the blossom bud until that time.

We will begin, then, at A, and follow it out:

79b. 1890. Started as a spur from the main branch A, and grew to 1.



28

FIG. 70.

The eventful history of an apple twig.

79c. 1891. Apple borne at 1. This apple did not mature, however, as we can readily see by the smallness of the scar. In this year, two side buds developed to continue the spur the next year.

79d. 1892. Gave up its desire to be a fruit-spur, and made a strong growth, to 12. For some reason, it had a good chance to grow. Perhaps the farmer pruned the tree, and thereby gave the shoot an opportunity; or perhaps he plowed and fertilized the land.

In the meantime, one of the side buds grew to 3, and the other to 7, and each made a fruit-bud at its end.

79e. 1893. Shoot grew lustily,—on to D.

The fruit-bud at 3 bore an apple, which probably matured, as shown by the scar 2. Two side buds were formed beneath this apple to continue the spur next year.

The fruit-bud at 7 bloomed, but the apple fell early, as shown by the small scar. Two side buds were formed.

The buds upon the main shoot—1 to 12—all remained dormant

79f. 1894. Shoot grew from D to E.

Side bud of 2 grew to 4, and made a fruit-bud on its end; the other side bud grew to 5, and there made a fruit-bud.

Side bud of 7 grew to 10, and the other one to 8, each ending in a fruit-bud.

Buds on old shoot—1 to 12—still remained dormant.

Some of the buds on the 1893 growth—12 to D,—remained dormant, but some of them made spurs,—14, 16, 17, 18, 19, 20, 21, 22, 23.

79g. 1895. Shoot grew from E to 28.

Flowers were borne at 4 and 5, but at 4 the fruit fell early, for the five or six scars of the flowers can be seen, showing that no one of them developed more strongly than the other; that is, none of the flowers "set." A fairly good fruit was probably borne at 5. At the base of each, a bud started to continue the spur next year.

Upon the other spur, flowers were borne both at 8 and 10. At 10 none of the flowers set fruit, but a side bud developed. At 8 the fruit evidently partially matured, and a side bud was also developed.

The buds upon the old stem from 1 to 12 still remained dormant.

Some of the spurs on the 1893 growth—12 to D—developed fruit-buds for bearing in 1896.

Some of the buds on the 1894 growth—D to E—remained dormant, but others developed into small fruit-spurs. One of these buds, near the top of the 1894 growth, threw out a long shoot, starting from G; and the bud at 26 also endeavored to make a long branch, but failed.

79a. 1896. Main shoot grew from 28 to the end.

The side bud below 4 (where the fruit was borne the year before) barely lived, not elongating, as seen above 3. This branch of the spur is becoming weak, and will never bear again. The side bud of 5, however, made a fairly good spur, and developed a fruit-bud at its end, as seen at 6.

The side bud of 10 grew somewhat, making the very short spur (11). This branchlet is also getting weak. The bud of 8, however, developed a strong spur at 9. Both 11 and 9 bear fruit-buds, but that on 11 is probably too weak ever to bear fruit again. In fact, the entire spurs, from 1 to 6 and 1 to 9, are too weak to be of much account for fruit-bearing.

This year several of the spurs along the 1893 growth—12 to D—bore flowers. Flowers were borne from two buds on the first one (at 13 and 14), but none of the flowers "set." One of the little apples that died last June still clings to the spur, at 14. A side bud, 15, formed to continue the spur in 1897. Flowers were borne at 16, 20, 21 and 23, but no apples developed. Upon 16 and 20 the flowers died soon after they opened, as may be seen by the remains. Upon 23, one of the flowers set an apple, but the apple soon died. The spurs 17 and 18 are so weak that they never have made fruit-buds, and they are now nearly dead. The spurs 19 and 22 seem to have behaved differently. Like the others, they grew in 1894, and would have made terminal fruit-buds in 1895, and borne fruit in 1896; but the terminal buds were broken off in the fall or winter of 1894, so that two side buds developed in 1895, and each of these developed a fruit-bud at its end in 1896 in the spur 19, but only one of them developed such a bud in 22. Upon these spurs, therefore, the bearing year has been changed.

Upon the growth of 1894—D to E—only three spurs have developed, Nos. 24, 25, 26. These started out in 1895, and two of them—25 and 26—have made large, thick buds, which are evidently fruit-buds. The shoot at G grew on to E E, and all the buds on its lower two-year-old portion remained dormant.

On the 1895 growth—from E to 28—all the buds remained dormant except one, and this one—27—made only a very feeble attempt to grow into a spur.

The buds upon the 1892 growth—1 to 12—are still dormant and waiting for an opportunity to grow.

80. What an eventful history this apple twig has had! And yet in all the seven years of its life, after having made fifteen efforts to bear fruit, it has not produced one good apple! The fault, therefore, does not lie in the shoot. It has done the best it could. The trouble has been that the farmer did not give the tree enough food to enable it to support the fruits, or he did not prune the tree so as to give the twig light and room, or he allowed apple-scab or some other disease to kill the young apples as they were forming. We may question, therefore, when trees fail to bear, whether it is not quite as often the fault of the farmer as the trees.

PART II

STUDIES OF LEAVES AND FOLIAGE

XV. WHAT IS A LEAF?

81. Is there one leaf, or three, in the picture of the dewberry (or blackberry) Fig. 71? We have already found that branches persist; that is, they do not fall upon the approach of winter. Leaves commonly die and fall. Here, therefore, is a means of answering the question. Does each of the three parts fall away in the autumn and leave the common stalk, *a*, upon the vine,

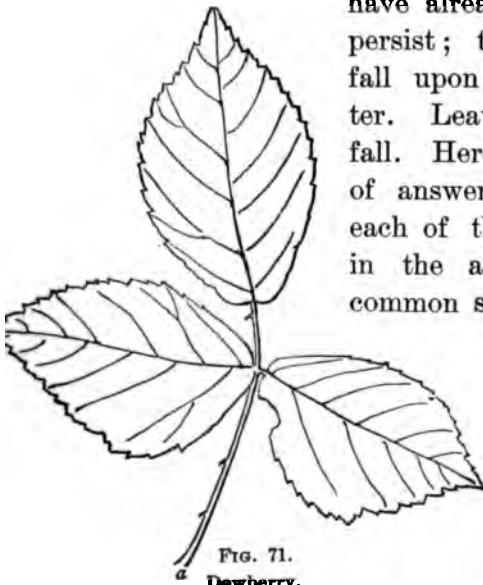


FIG. 71.
Dewberry.

as a branch? Or does the entire structure fall?

82. Buds are formed in the axils of leaves, as a rule. Where are the axillary buds

in the dewberry,—in the axils of each of the three parts, or in the axil of the stalk *a*? Again, leaves are borne at nodes; and the

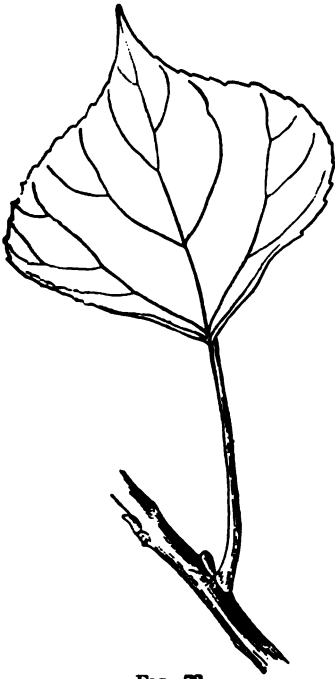


FIG. 72.

Leaf of Lombardy poplar.



FIG. 73.

Spray of young apple leaves.

plant axis upon which they are borne either extends beyond them or gives evidence that it may do so.

83. What comprises the leaf in Fig. 72 (the



Lombardy poplar)? Is the leaf the expanded portion, or is it that portion plus the stalk? Let the pupil apply the above tests, and answer.

84. In the young apple foliage (Fig. 73), what comprises the leaf,—the expanded portion, the stalk, the two awl-like bodies at the base, or all of them together? How many leaves are there on the branch?

85. Point out the extremities of the leaf in the wheat (Fig. 74), or in any grass. Does it attach to the stem at 1 or at 6?

86. Designate the leaves in Figs. 75 and 76, and give the proofs.

XVI. THE PARTS OF LEAVES

87. We are now ready to believe that a leaf may have two or three distinct parts,—the expanded portion or blade, the stalk or petiole, and appendages at the base, or stipules. We also know that it may have only the blade, as in the live oak leaves in Fig. 77; and it may have only the petiole or the stipules.

FIG. 74.
Leaf of wheat.

For example, we have seen that the bud-scales of the black currant (Fig. 51) gradually pass into leaves; but the leaves are borne on the ends of



FIG. 75.
Honeysuckle.

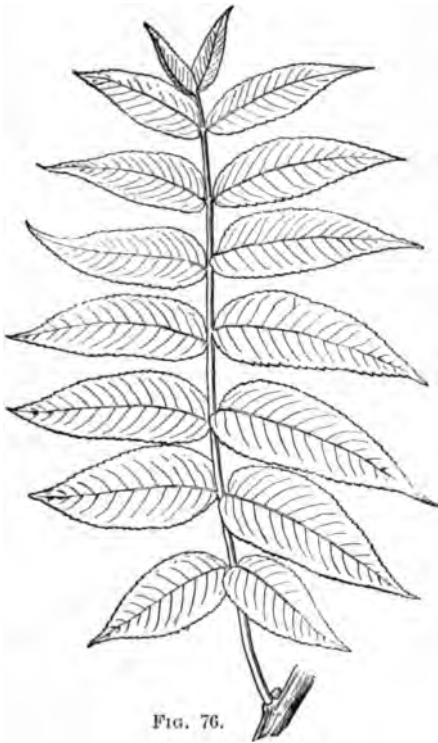


FIG. 76.
Black walnut.

scales; therefore, the scales must represent transformed petioles, not transformed blades. If the enlarged and green bud-scales of the Norway maple

(Fig. 50) are petioles, we have an example of leaf-stalks which perform functions of leaf-blades.



Various leaves of live oak.

Leaf of a willow.

88. The leaf of a willow is shown in Fig. 78. The stipules are so leaf-like as to indicate that they

must act the part of foliage (*i. e.*, perform the functions of green leaves). If, for any reason, the leaf-blades were to perish, it is conceivable that the stipules could maintain the plant. This actually

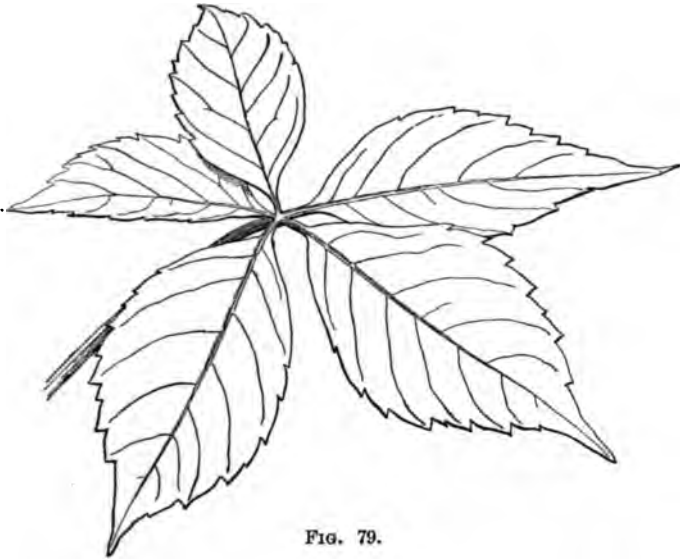


FIG. 79.

Virginia creeper.

occurs in some plants (as in some of the vetches), in which the entire foliage is made up of large stipules.

88a. Some of the members in Fig. 63 are probably leaf-like stipules. A leaf which has no petiole is said to be sessile (*i. e.*, "sitting"), a term applied to any member which is destitute of a stalk or stem.

89. How shall we define the parts in the leaf of

the Virginia creeper (Fig. 79)? The petiole is plain; but shall we say that there are five distinct blades, or that the blade is divided into five parts? Figs. 80 and 81 are leaves from one grape vine.



FIG. 80.
Grape leaf.



FIG. 81.
Deeply-lobed grape leaf.

Each plainly is one leaf. The former has three well marked lobes, and the latter has these lobes much more deeply cut. In fact, there are strong indications of five parts. It is not difficult to imagine the clefts extending to the mid-rib, as they

do in the Virginia creeper (which is a very closely related plant), and a compound leaf would be the result (that is, a leaf in which the blade is composed of at least two wholly separated portions).

90. Each part of the Virginia creeper leaf (and also of the dewberry leaf) is borne upon a distinct



FIG. 82.
Bean leaves.

stalklet of its own. These stalklets, then, are secondary petioles, or petiolules.

91. Bean leaves (Fig. 82) are seen to be compound, with both petiole and petiolules. Moreover, these petiolules are provided with little stipules, or stipels. Let the pupil now determine if there is a

joint at any place on the petiolules at which point the three parts may break off in the fall; and is the Virginia creeper like the bean in this respect?

92. The leaf of the Canada thistle (Fig. 83),—and of most other thistles,—is variously cut or jagged, but is nowhere completely separated, and is not, therefore, a compound leaf. We have seen, then, that there are various gradations between the simple leaf (that is, one in which the blade is one



FIG. 83.

Canada thistle.

more or less continuous piece, as in Figs. 72, 73, 74, 77, 78), and the compound leaf. In the true compound leaf the parts are generally articulated (or separated by joints), and are, therefore, usually provided with petiolules, although these are sometimes wanting. The different parts may fall independently of the entire leaf, or they may not.

93. Inasmuch as there seems to be a well

marked difference between the distinct divisions in the Virginia creeper and the ill-defined ones in grape and Canada thistle, we may give the two types different names. Or, the parts of a compound leaf are leaflets; the deep cut parts, like those in the thistle, are divisions or segments; the shallower parts (ordinarily not extending more than half way to the midrib) are lobes, as in Fig. 81.

SUGGESTIONS.—The pupil will now find himself applying the foregoing tests to all the leaves which he meets. Let him determine whether any plant bears both simple and compound leaves. He may be interested in examining the so-called Boston ivy or Japanese Virginia creeper which is much planted for covering houses; also, the horse-radish (examine the very earliest leaves in spring); also, one of the cultivated forsythias or yellow bells (the so-called climbing one, *Forsythia suspensa*).

XVII. THE COMPOUND LEAF

94. The leaflets of the dewberry and Virginia creeper arise from a common point,—the top of the petiole. If the blade of the thistle (Fig. 83) were compound, the leaflets would evidently be distributed in two rows along a central axis. Compare Figs. 84 and 85. There are, then, two distinct types of compound leaves,—the *digitate* or *palmate* (in which the leaflets are at-

tached to a common point, like the bones of the hand to the wrist, and the petiole shows no tendency to continue beyond the point of their attachment); and the pinnate (in which the leaflets are arranged on the sides of an axis like the parts of a feather). The axis is prolonged in

the pinnate leaves, and the part beyond the first leaflet is called a rachis.



FIG. 84.

Leaf of poison ivy.

95. If, now, the leaflets in Figs. 71, 79, 84 were grown together, what would be the method of attachment of the main veins or ribs in the resulting simple leaf? If the grape leaf (Figs. 80, 81) were to become compound, would it

be palmate or pinnate? Would the oak (Fig. 77) have palmate or pinnate leaves? Why would the thistle leaf (Fig. 83) become pinnate rather than palmate? Let the pupil examine various kinds of leaves, and determine if simple leaves are either palmate-veined or pinnate-veined.

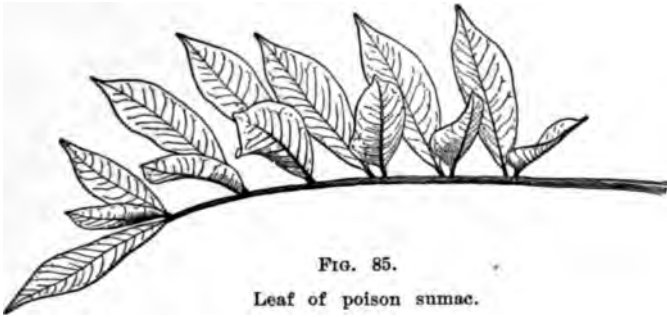


FIG. 85.

Leaf of poison sumac.

96. The Virginia creeper leaf has five leaflets, or is quinate (parts in fives). The dewberry and the poison ivy have three leaflets, or are ternate (part in threes). The jeffersonia (Fig. 86) has two leaflets, or is binate. Is this jeffersonia leaf essentially palmate, or essentially pinnate?

97. A leaf of the squirrel-corn (or dicentra) is shown, Fig. 87. It is evidently ternate and palmate; but each part is again divided into three, and each of these is again variously divided and cut. The leaf, therefore, is biternate (or twice ternate). The



FIG. 86.

Binate leaf of jeffersonia.

entire leaf is said to be decompose (a term applied to all leaves in which the leaflets are compound; that is, to leaves which are more than once compound).

98. It is plain that there is no positive or

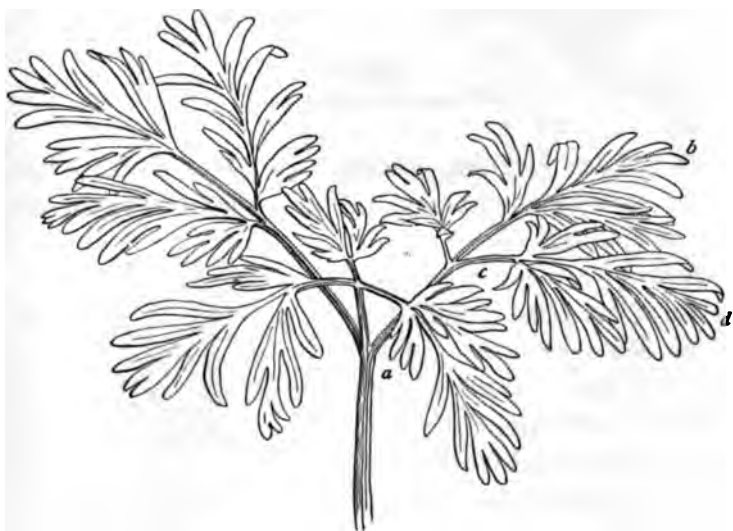


FIG. 87.

Leaf of squirrel-corn.

definite number of ultimate divisions in this dicentra leaf. (Let the pupil examine the bleeding-heart of the gardens, which is also a dicentra.) These ultimate parts are, therefore, not leaflets, but segments or divisions. Is the leaflet the portion extending from *a* to *b*, or from

c to *d*? It is the latter; that is, it is customary, in speaking of decomposed leaves, to use the term leaflet for the last part which is clearly and completely (and more or less uniformly) separated from its neighbors.

98a. The primary divisions in a palmately decomposed leaf (as *a b*) are not given a distinct name in general botanical literature. The botanist would describe this dicentra leaf (Fig. 87) nearly as follows: Leaf ternately decomposed (or sometimes written ternately compound, if the degree of compounding is afterwards specified), the main sections bearing palmately—or even pinnately—divided leaflets, the segments again deeply cut or divided.

99. The leaf in Fig. 88 (a gum arabic tree, a kind of acacia) is decomposed, and is pinnate. Each of the numerous entire pieces or parts is called a leaflet, and the six primary parts are pinnæ. The leaf is pinnately bi-compound (or twice-compound). If each of the leaflets was again compound—which is not very rare in plants of this family—the leaf would be said to be tri-compound; the primary parts would still be called pinnæ, the secondary parts pinnules, and the last complete divisions leaflets.

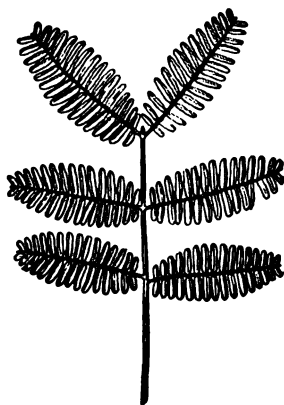


FIG. 88.

Twice-pinnate leaf of
acacia.

100. This acacia leaf has no terminal leaflets.

Compare the poison sumac (Fig. 85). That is, one is abruptly-pinnate, like the honey locust and the peanut (having no terminal leaflet), and the other is odd-pinnate. The latter is the more common form. Leaves are fairly constant



FIG. 89.

Spray of Currant tomato.

in these characters, but the pupil will be interested to find exceptions. Let him examine, among others, the leaves of black walnuts and butternuts.

101. Leaves of a tomato are shown in the

spray in Fig. 89. All the leaves have two kinds of leaflets,—certain ones which may be taken as the normal size, and other small ones interposed. This kind of leaf is common in the tomato and potato tribes. On account of the intermediate leaflets, such a leaf is said to be interrupted. This one, then, is interruptedly pinnate.

102. Another tomato leaf is shown in Fig. 90.



FIG. 90.
Leaf of Mikado tomato.

In this instance there are no interposed leaflets, but the leaflets vary much in size and shape. In other words, it is an example of an irregularly compound leaf. The leaf looks as if it



might represent foliage of an indefinite form; or, in other words, that there is no absolute and typical form of tomato leaves. Let the pupil examine many tomato plants, and see if this is true.

103. The dahlia leaf is peculiar (Fig. 91). In this specimen there are five well-defined leaflets, C, O, M, M, A; but one of these, A, has given rise to a strong segment or division, and two others have divisions which are sufficiently distinct to be called leaflets. There are various grades of dividing or compounding, and the leaf may be said to be mixed. It is incompletely bi-compound.

104. From observations on leaves, we are soon impressed

with the multitude of forms. We are also impressed with the fact that there may be great variety,—or elasticity,—of forms in the same kind of plant, showing that nature is really informal. Definitions, however, are formal; and it, therefore, follows that definitions should be compared with the objects, not the objects with the definitions.

The terminology (or naming) of compound leaves may be further explained, as follows:

104a. In making compounds to express the number of leaflets, the Latin for leaflet (*foliolum*) is used, not the word for leaf (*folium*); a trifoliate leaf is, therefore, an impossibility. It is like saying "three-leaved leaf." However, usage has sanctioned its employment, although it is etymologically improper. The better forms are—

Unifoliate, a compound leaf of one leaflet;

Bifoliate, of two leaflets;

Trifoliate, of three leaflets;

Quadrifoliate, of four leaflets;

Quinquefoliate, of five leaflets;

Plurifoliate, of several or many leaflets.

Any of these terms may be applied to either digitately or palmately compound leaves.

104b. The degree of compounding is often specified as follows:

Compound, once compound,

Bi-compound, twice compound, etc.;

De-compound, more than once compound, without specifying the degree.

Similarly, pinnately compound leaves may be designated as *bipinnate*, *tripinnate*, etc.; and palmately compound ones as *bipalmate*, *tripalmate*, etc. As a matter of fact, palmate leaves are rarely decompound if they have more than three primary divisions; so that it is customary to speak of palmately compound leaves as *ternate*, *biterminate*, *triterminate*, *multiterminate*, etc.

104c. Leaves which are strongly lobed or divided receive names of

similar makeup. Lobed leaves are those in which the divisions are not more than half the depth of the blade; cleft leaves have the divisions extending deeper than the middle; parted is used for still deeper sections; and divided for those leaves which are cut nearly or quite to the midrib, but in which the parts (or divisions or segments) are not distinct enough to be called leaflets. Lobed and cleft leaves are designated in botanical phrase as bifid, trifid, quadrifid, multifid, etc.; parted and divided leaves are designated as bisect, trisect, etc.

Pinnately-lobed leaves are pinnatifid; pinnately-divided leaves are pinnatisect (but there are no corresponding palmatifid and palmatisect in general use). Compound leaves which are cut and divided very much and more or less indefinitely (as in Fig. 87) are said to be dissected, whether pinnate or palmate.

SUGGESTIONS.—The venation of a leaf (or petal) is the arrangement and other features of the veins or ribs. Let the pupil collect abundantly of leaves (and indiscriminately, if he choose), and match the venation in them. Possibly he may find his pencil useful in recording and interpreting the differences.



FIG. 92.

Shoot of speed-
well.

XVIII. DISGUISES OF LEAVES

105. We have noticed how varied and disguised the parts of leaves may be, upon occasion. Fig. 92 is a sprig of a common weed, the veronica or speedwell. The normal leaves are shown at the base; but they become gradually smaller as the top is approached, and finally are little more than scales.

Such gradations are very common, especially in

herbs. These reduced leaves are known as bracts. Sometimes bracts remain green and leaf-like (as in this case), when they differ from leaves only in their greatly reduced size. At other times they are mere dry or membrane-like scales, and are then often called dry or scarious bracts.

106. The pupil will now be interested in Fig. 93, the leaf of the common pea. (Examine, also,

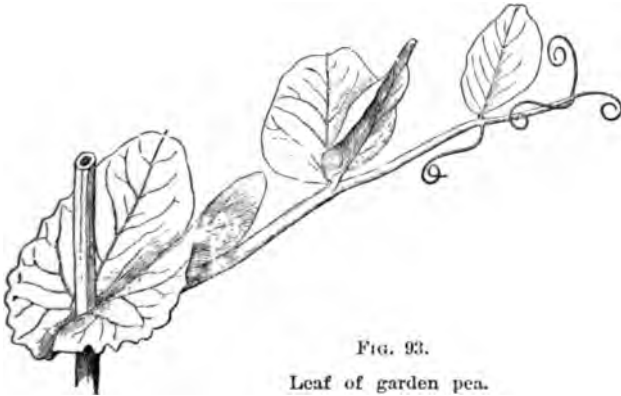


FIG. 93.
Leaf of garden pea.

the sweet pea.) How many pairs of leaflets has it? At the base are two very large and leafy stipules; then follows a pair of leaflets and,—what has become of the other leaflets?

107. The cobea is a climbing plant of gardens and conservatories. Its leaf normally ends in a tendril (Fig. 94). There are three pairs of leaflets. Fig. 95 is a leaf which is reduced to a



FIG. 94.

Normal leaf of cobea.

single pair of leaflets, but each leaflet is curiously lobed, and tendrils are springing from the end. We are now convinced that tendrils may be modified parts of leaves.

108. This leaf in Fig. 95 is interesting, because it shows also a variation or change which is

foreign to the normal type or tendency of the leaf. That is, we know that the terminal leaflet in the cobea is a tendril; if other tendrils appear, we should expect them to arise from the complete transformation of one of the lateral leaflets. Instead of this normal behavior, however, the lateral leaflets have become strangely shaped, and tendrils



FIG. 95.

Monstrous leaf of cobea.

are endeavoring to form in most unusual places.

108a. Such strange and abnormal variations or transformations as these, wherever they occur, are known as monstrosities (or monstrous forms). The dahlia leaf (Fig. 91), is not a monstrosity, because it assumes a form which is habitual to the plant and which conforms with its general structure.

109. A pitcher plant, or spotted trumpet leaf, of the South, is drawn in Fig. 96. There is a similar species in northern bogs. The structure and its position upon the plant both show that it is a leaf. Here, then, the leaf is a pitcher or water-holding receptacle, and the mass of captured insects and other animals is no doubt digested and absorbed as plant-food.

109a. It is known that certain plants absorb the juices of insects which are caught in traps and killed, and that others make use of the accumulated mass of organic matter or humus which is caught in various kinds of cups or receptacles. The pupil who desires to pursue this interesting subject should begin by procuring Darwin's work on "Insectivorous Plants." Geddes' "Chapters in Modern Botany" will be useful. There is a large special literature.



FIG. 96.
Leaf of pitcher
plant.

110. Let us return to the bean, Fig. 82. Is it pinnate or digitate? It is certainly digitate in form;

but the petiole (or rachis) extends beyond the pair of leaflets, as may be seen by the joint

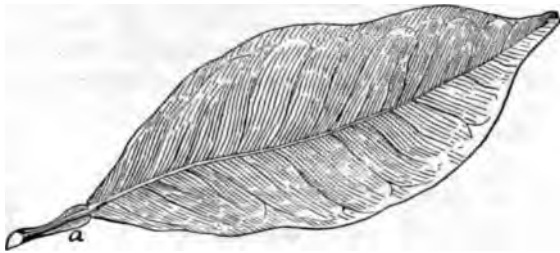


FIG. 97.

Leaf of orange.

in the petiolule of the terminal leaflet. The leaf, then, is evidently pinnate; and if homology will



FIG. 98.

The compound-leaved orange.

aid in the interpretation, the pupil will be interested in examining the leaves of peas, ground-nut or apios, and other relatives.

111. An orange leaf is shown in Fig. 97. There is a large blade, a winged petiole, *a*, and a distinct joint or articulation be-

tween the two. This articulation suggests that the leaf may be the remnant of a once compound leaf. A closely related plant—the so-called trifoliate orange—is shown in Fig. 98, and here the leaf is compound, with the joint below the three leaflets. It is generally considered that the orange and the



FIG. 99.

Leaves of the barberry.

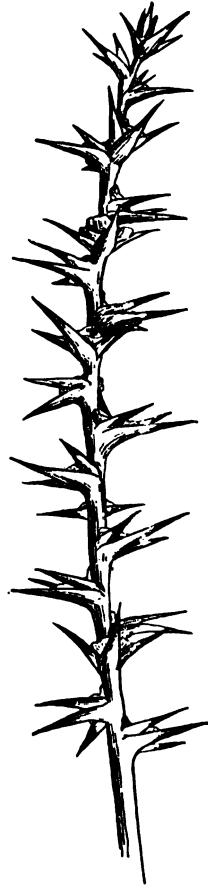
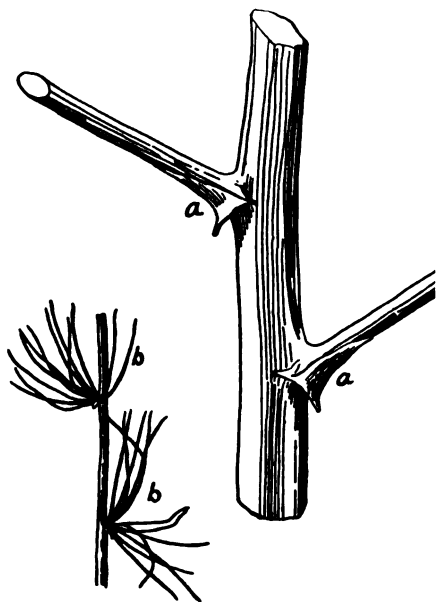


FIG. 100.

Spinescent leaves of the Russian thistle.

lemon leaf is a unifoliate (or one leaflet) compound leaf.

leaves, and may be interp



foliar leaves to spines. The spines are mostly three-branched, as in the illustration, but they are sometimes forked, and often simple. The three-parted spines of the Russian thistle (Fig. 100) may also be interpreted as leaves, because the flowers and branches arise from their axils. The spines in Fig. 98 are branches, however, because they are borne in the axils of the leaves; but a supernumerary bud produces the flowers.

112a. Is the barberry leaf simple or compound? Look for a joint near the base of the petiole, and compare with the orange in Fig. 97. Some kinds of barberries have pinnate leaves.

SUGGESTIONS.—The pupil should give particular attention to spines and thorns, and endeavor to interpret them as suggested above. He should visit bushes of the common wild hawthorns (often known as thorn-apples) soon after growth begins in the spring, and watch the development of the spines. He should look for any evidence of leaves. Any thorny tree or bush will repay an inquisitive visitor at any time of the year.

XIX. DISGUISES OF LEAVES, CONCLUDED

113. The common asparagus is shown in Fig. 101. The specimen at the left represents the tender shoot, which we eat. The scales should be called leaves or bracts, as may be seen by their phyllotaxy and by the fact that branches later spring from their axils (*a, a*). Let the pupil examine an asparagus plant in "full leaf," and notice that

111. The so-called smilax of florists (in decoration) is closely allied to the a



FIG. 102.
Spray of florists' smilax.

g. 102.) The leaves are seen to be m
les, while the branches have developed
ded leaf-like bodies, and the flowers a
n supernumerary buds (recall the oran
. A further proof that these foliaceou
branches occurs in the closely allied
sm of the Old World, in which a

114a. Branches which imitate leaves are called cladophylla (word meaning "branch-leaves;" singular, cladophyllum).

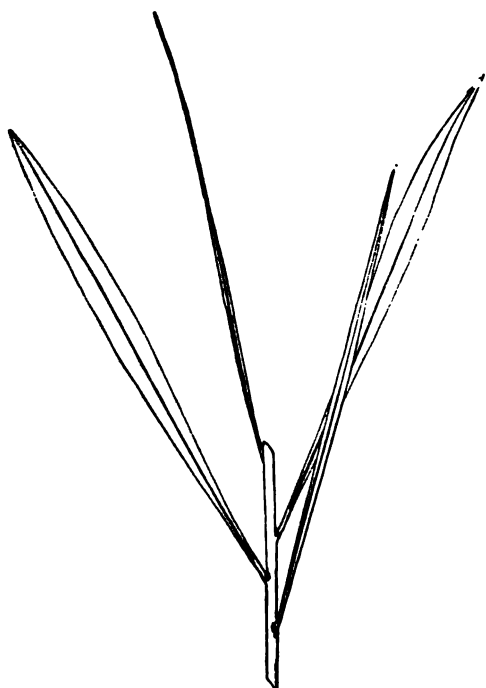


FIG. 103.

Foliage of an acacia.



FIG. 104.

Foliage of another acacia.

115. A leaf of the long-leaf acacia (from Australia, now sometimes grown in glass houses) is shown in Fig. 103. It is typical of a class of acacias. This leaf has a peculiar, rigid structure, and it stands edgewise to the branch; these facts,



105.
res of

116. Another acacia is shown
104. Here the phyllodia are
standing edgewise. But there
spines beneath them. If the
of mere position is to be follo
should consider these phyllodia to
ophylla; but the leaves of you
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the phyllodia. If, now, we retur
phyllodia in Fig. 103, we notice
scar at the base of each (indi
the spot at the base in the pictur
mark is not uncommon in these
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stipules. It is seen, therefore, h
the importance of very obscure c
may be when one studies the ch

determine whether the number of leaves in a cluster is characteristic of each.) Are these five bodies leaves, or branches? If the evidence of mere position is proof, however, they are cladophylla, for they are borne in the axils of scales. Each bundle is enveloped at its base in a sheath, and this sheath, with its leaves, is sometimes plainly axillary; but the sheath is probably homologous with bud-scales. There are morphological reasons, also, for calling them leaves. The point is, that it is often difficult to interpret a given form correctly by the application of an arbitrary rule.

117a. Let the pupil examine a growing shoot of pine (in spring), and observe the position of the dry scales, which sometimes fall away and leave only the scar-like evidence of their presence. See Obs. lviii. (In Fig. 105, the sheath has been worn away by the elements.) Let him notice, if, at the base of the new growth, there are scales from which no leaves arise, as there are leaves in similar positions upon other trees from which no branches arise (42). For further light upon the subject, he will be interested to examine the fasciated (or clustered) leaves of the larch or tamarack.

117b. The pupil will now examine the leaves of spruces and firs. These leaves are placed singly, and it is difficult to make them out to be axillary to scales; and this may throw some light upon the nature of the leaves of the pine.

117c. The pines and spruces are commonly known as "ever-greens," because they never lose their foliage. This does not necessarily mean, however, that their leaves never fall. In fact, we know that the leaves do fall, for we remember seeing the ground under old pine trees covered with needles; and we know, too, that the interior of the top of a pine tree is brown and dull, not lively green, as it would be if the leaves were still intact. We should not expect the leaves to persist inside the

118. From all these observations, it is that the leaf-idea is a most variable outward structure. The leaf normally serves a certain function: that is, it performs certain functions in the life and growth of the plant. Branches may perform this function just as well as leaves. A leaf may be modified endlessly, and may cease to be a functional part (that is, cease to take part in the life-processes of the plant). It is not possible to determine what are leaves and what are not, in certain cases, then it is likewise impossible to define a leaf; but practice in defining a leaf may be useful in fixing the notion of the leaf-idea in the pupil's mind. It is more important to dwell upon differences than upon uniformities; for, as we have already said, variations are among the most striking facts in nature.

words, an organ is a part of an organized (living) body directly associated with the vital functions, as are the heart and lungs of animals. A member is a distinct or integral external part, as a wing or a stamen, especially one which is not directly concerned in the maintenance of the vital functions. In plants, many parts are at once both organs and members, as the leaves; when one is considering these parts from the standpoint of morphology or form, it is well to speak of them as members, but in a book upon physiology they might be spoken of as organs.

118b. We are now prepared to understand that the old idea of the "complete" leaf—one which comprises blade, petiole and stipules—is simply an inference. It is not a type or unit in nature, of which the "incomplete" leaves are modifications. The "complete" leaf is itself the exception, perhaps, and is only one of the many types of variation which occur in the leaf-member.

118c. The idea of leaf, as defined by an arbitrary position assigned to it upon the stem, comprises a most heterogeneous set of members, as we have seen. When we say that spines are modified leaves merely because they occupy the position of leaves, we are going beyond our knowledge. It is only now and then (as in the case of the barberry) that we have the evidence of intergradient forms. For purposes of definition, it is well to say that such and such spines occupy positions which leaves normally occupy; but beyond this it is not often safe for the beginner to go.

118d. Advanced study of morphology and embryology may show the true nature of any member, and it is generally able to distinguish clearly between leaves and stems; and may be the only conclusive resource in cases which are very difficult of interpretation.

SUGGESTIONS.—The pupil should now challenge every leaf, spine, tendril and scale he meets, for each one means something. He should make observations to determine how many of the plants which he commonly sees have stipules, petioles and blades, and how many lack one or more of these parts.

is the same (or almost) in the apple (Fig. 8), maple (Figs. 13, 14), rhododendron (Fig. 52), and quince (Fig. 53). It is usually the same in all of them. The enlargement of the petiole is slightly expanded, but the insect mode of attachment is called) may be ordinary.

120. Now compare the dahlia (Fig. 91). The base of the petiole is dilated; and it is observed that in this particular case the two opposite petioles cohere, and explain the ring-like leaf-scar of the stem shown in Fig. 38. When two sessile leaves cohere, they are said to be connate (Fig. 91).

121. Sessile leaves have various modes of attachment. Fig. 107 is the common mulberry. The leaf runs down the stem, and the leaves seldom fall away with a distinct a

are said to be auriculate. If the blade completely surrounds the stem (Fig. 109), the leaf is perfoliate.



FIG. 106.

Connate leaves of honeysuckle.

FIG. 107.

Decurrent leaf of mullein.

122. The question was raised (85) as to the point of attachment of the wheat leaf. It was probably decided that it is attached at 6. (See



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FIG. 110.

Ocrea of rhubarb.

docks, and sorrels, is technically known as an ocrea (that is, a "boot"). It is considered to be formed of the union of two stipules.

124. Observe the manner in which the petiole is attached to the blade of the leaf. In the barberry (Fig. 99) it is gradually merged into the blade. Such a leaf is described in terms of the

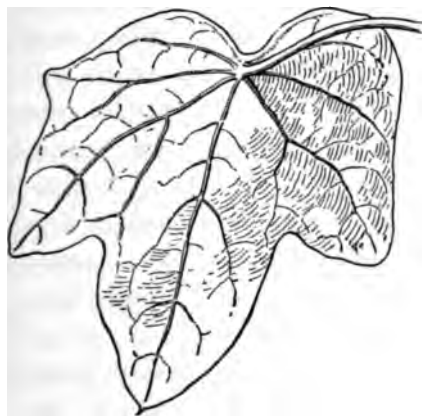


FIG. 111.

Peltate leaf of moonseed.

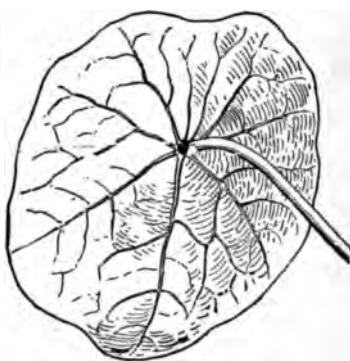


FIG. 112.

Peltate leaf of nasturtium.

blade; that is, the blade is said to be narrowed into the petiole. Observe the attachment in the maple, grape, and apple leaves. In them—and perhaps in the greater number of leaves—the attachment of the petiole is more or less definite, and is made to the edge of the blade.

125. The leaf of the common moonseed is shown in Fig. 111. This shows a different arrangement. The petiole is attached just inside the border or edge of the blade. In the common nasturtium (or *tropæolum*) of the gardens (Fig. 112), the petiole is inserted almost centrally. Leaves in which the petiole is inserted inside the edge of the blade are said to be peltate (that is, "shield-like"). This mode of attachment may occur even in much-divided leaves. The pupil will recall the may-apple or mandrake. Compare the leaves of water-lilies, and of other plants which have floating leaves. If the leaflets of a digitately-compound leaf were to grow together, the leaf would be peltate; but the pupil must determine if true digitate leaves are ever peltate.

126. The petiole, then, has no necessary relation with the leaf in size or in method of attachment to the blade; and many leaves are wholly sessile. A consideration of tapering leaves (as the barberry) suggests that the petiole may have arisen originally as a prolongation and modification of the midrib, or as the result of an elimination of a part of the blade. The pupil may now inquire what purpose, if any, the petiole serves; and he should be able to suggest an answer to the question.

SUGGESTIONS.—The pupil should determine why some leaves are rigid (or seem to stand stiff on the plant), and why others droop and hang. Is it ever because of the positions in which the leaves are borne, or of some peculiarity of the petiole, or method of attachment? Why do poplar leaves shake in the slightest breeze? Observe the lengths of petioles in sunlight and in shade; also of leaves floating upon deep water. Are floating leaves often peltate?

XXI. THE FORMS OF LEAVES

127. The forms of leaves (and of leaflets) interest us in two directions,—in respect to the relation which they bear to the welfare and history of the plant (or to adaptation to particular purposes of the plant), and in respect to their use in enabling us to recognize and describe plants. The former subject cannot be considered here. We shall, therefore, define the forms for purposes of description; but in doing this we must remember that there is every grade of intermediate form. Certain geometrical figures or arbitrary ideals are taken as the standards of comparison, and it must



FIG. 113.

Lanceolate leaves of
red pepper.

not be expected, therefore, that typical examples of the various forms are necessarily to be found in nature.

128. One of the first conceptions of forms of leaves which it is necessary to apprehend is that of the lanceolate (or lance-shaped) leaf. Lances were of



FIG. 114.

Ovate leaves of red pepper.

various shapes, but the botanical conception is a form four to six times longer than wide, and tapering at both ends, but the widest part is usually conceived to be below the middle. The leaves of the red pepper (Fig. 113) are examples.

129. Perhaps the next conception in importance

is that of the ovate leaf. This is about twice as long as broad, tapering from near the base to a narrow or pointed apex. The leaf at *a* in Fig. 114 (another form of red pepper) is an example.

130. A third type form is the oblong leaf. This is about twice as long as broad, with the sides nearly parallel from top to bottom. Typical oblong leaves are rare, but the form is freely used in combination with the lanceolate and ovate types. Thus the chestnut leaf (Fig. 115) is oblong-lanceolate. The orange leaf (Fig. 97) is ovate-oblong; so are the cladophylla of Fig. 102. In these combinations, the second word is the one which is to be chiefly emphasized; that is, an oblong-ovate leaf is one which is more ovate than oblong, whereas an ovate-oblong leaf is one more oblong than ovate. The narrower leaves in Fig. 114 are lance-ovate (*i. e.*, lanceolate-ovate).



FIG. 115.

Oblong-lanceolate leaf of chestnut.

ly, or triangular; cuneate, or wedge-shaped, or linear, or several times longer than broad, and the same throughout; needle-shaped, pines and spruces. If any of the type forms are reversed or inverted, the fact is expressed by the prefix *ob*, oblongate, obovate. Combinations of these terms, together with the use of familiar adjectives (as short-ovate, long-ceolate, round-obovate, etc.) express most of the common outlines of leaves.



FIG. 116.
Ovate crenate leaf
of catnip.

2. Aside from the general outline, the leaf is determined by the shape of the apex and base. The apex may be acute or

shaped (as in Fig. 116, which is a cordate-ovate leaf); reniform, or kidney-shaped; auriculate, or eared; sagittate, or arrow-shaped; abrupt, or suddenly narrowed to the petiole (as in the broader leaves in Fig. 114); gradually narrowed (as in Figs. 97, 99). The cavity or recess in the base of a leaf, like the grape or moonseed, (Figs. 80, 81, 111) is a sinus.

133. The features of the margins of leaves, like their forms, are interesting because they are intimately related to the origin or evolution of the particular leaf (and, therefore, of the plant), and also as a means of affording descriptive characters. The simple straight margin is said to be entire (Figs. 85, 102, 113, 114). Departures from this form are the serrate, or saw-toothed (Fig. 91); dentate, or toothed (Figs. 79, 80, 115, the last being, perhaps, intermediate between serrate and dentate); crenate, or scalloped (Fig. 116); repand, or wavy, or undulate (Fig. 112 is obscurely so); sinuate, which is a deep undulation; and then follow the deep margins, as cut, jagged, lobed, cleft, and the like, to which we have already given attention (104c).

133a. The diagrams of forms and margins of leaves given by Linnæus are reproduced in exact form and size in Fig. 117: 1, orbiculate; 2, sub-orbiculate (or subrotundate); 3, ovate; 4, oval, or elliptical; 5, oblong; 6, lanceolate [narrower than present bot-

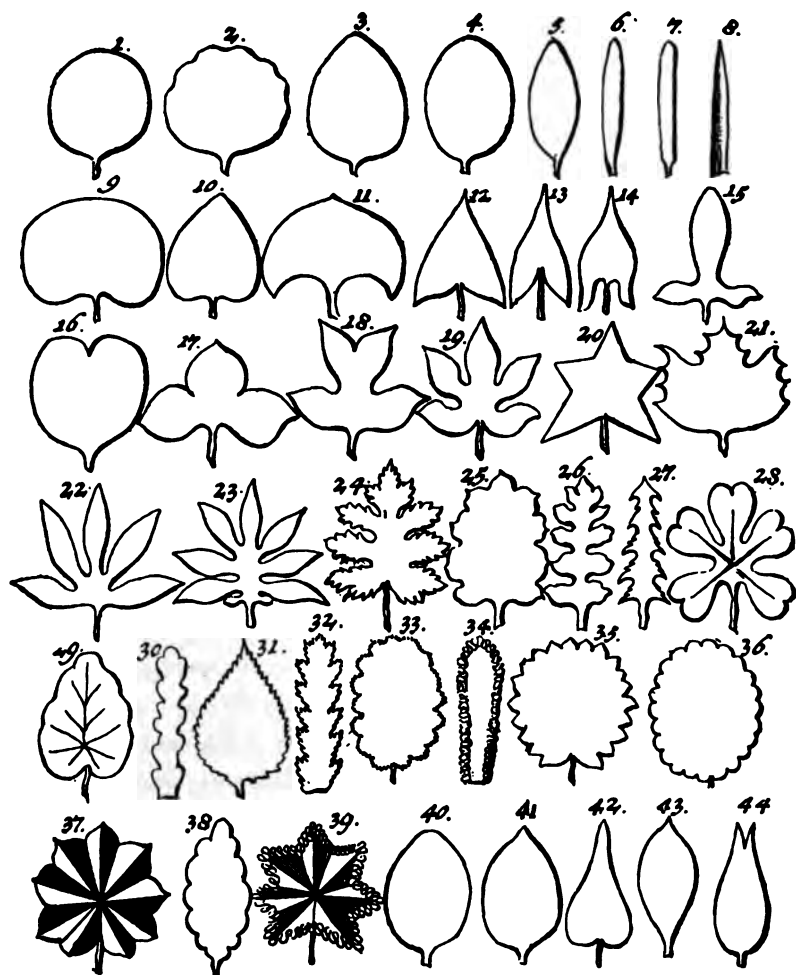


FIG. 117.

Linnaeus' diagrams of leaves. 1751.

anists define lanceolate to be]; 7, linear; 8, subulate [awl-like]; 9, reniform; 10, cordate; 11, lunulate [or crescent-shaped]; 12, triangular; 13, sagittate; 14, cordate-sagittate; 15, hastate; 16, cleft ["fissum," now called obcordate]; 17, three-lobed, or trilobate; 18, premorse [irregularly notched at the end]; 19, lobed, or lobate; 20, five-angled; 21, erose [jagged or bitten]; 22, palmate; 23, pinnatifid; 24, laciniate; 25, sinuate; 26, dentate-sinuate; 27, retrorse-sinuate; 28, parted; 29, repand; 30, dentate; 31, serrate; 32, doubly-

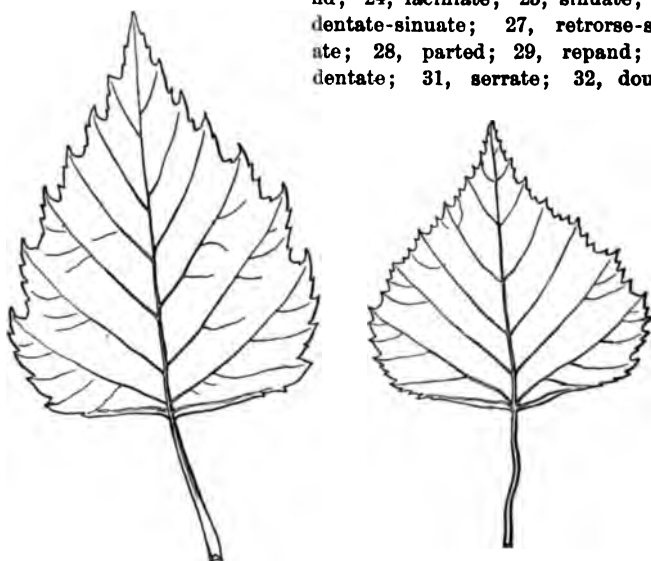


FIG. 118.

Variation in birch leaves.

serrate; 33, doubly-crenate; 34, cartilaginous; 35, acutely-crenate; 36, obtusely-crenate; 37, plicate; 38, crenate; 39, crisped; 40, obtuse; 41, acute; 42, acuminate; 43, obtusely-acuminate; 44, emarginate acute.

SUGGESTIONS.—We have said (127) that the forms of leaves are described by comparing them with purely arbitrary measures. We should not expect them always to match these measures; in illustration of which, let the pupil cut the form of any leaf in paper,

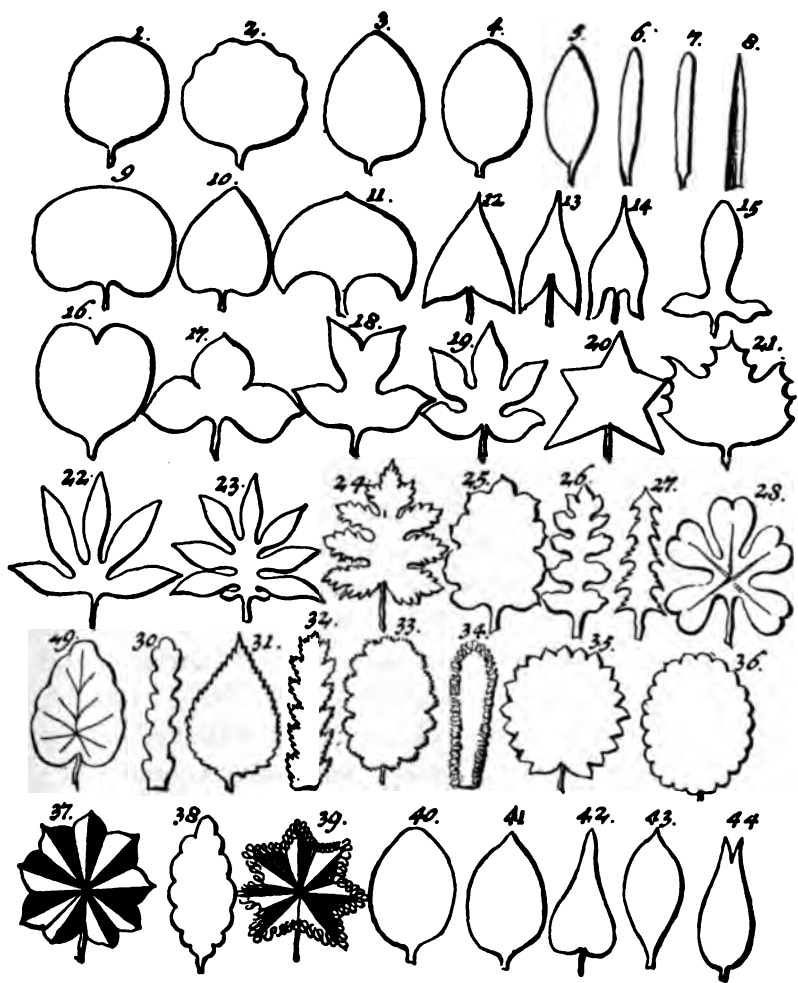


FIG. 117.

Linnæus' diagrams of leaves. 1751.

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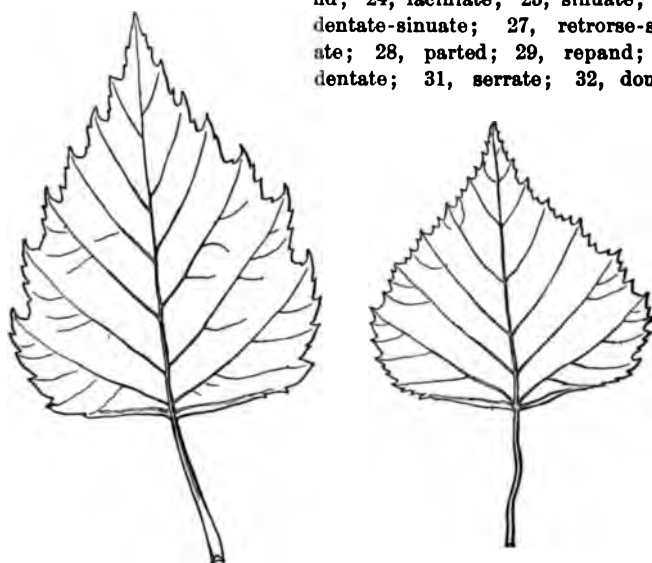


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SUGGESTIONS.—We have said (127) that the forms of leaves are described by comparing them with purely arbitrary measures. We should not expect them always to match these measures; in illustration of which, let the pupil cut the form of any leaf in paper,

and then endeavor to match it in other leaves. He will soon discover how difficult it is to describe a leaf with accuracy, and he will also apprehend the greater truth that there are probably not two leaves alike.

XXII. VARIATION IN LEAVES ON THE SAME PLANT, AND ON DIFFERENT PLANTS OF THE SAME KIND



FIG. 119.

Variable leaves of *smilax*.

134. The two birch leaves (Fig. 118) are from the same tree. They differ in size, shape, and dentation (or toothing). There was also a difference in color and in season of maturity. Now, let the pupil gather many leaves from one plant, and determine if he can find any two of them alike. He will recall our studies of the buds and branches, and will be inclined to conclude that there is universal difference in the members of plants.

135. The live oak branch in Fig. 77 will now

have new interest. The leaves upon the older (or lower parts) are normally entire, but the uppermost ones are distinctly sinuate. A different type



FIG. 120.

Different forms of leaves on a mulberry branch.

of variation may be found in the leaves of some kinds of smilax or greenbrier (Fig. 119). The illustration is of a southern species. The pupil should now study the leaves of grape (Figs. 80,

81), sassafras, tulip tree, mulberry (Fig. 120), and other plants, with respect to variations. He probably will find that variations in lobing are commonest upon the strongest or most verdurous shoots, and that variations in size are often associated with position in reference to sunlight.



FIG. 121.

Primary foliage
of red cedar.



FIG. 122

Primary and secondary leaves
of red cedar.

135a. The pupil who has access to greenbriers (they are common North and South) should endeavor to determine the significance of the scales *a a a*, Fig. 119.

135b. Do the abnormally-lobed leaves on the young shoots of grape, mulberry, and the like, remain the same in form throughout the season? Or, are these variously-lobed leaves more abundant early in the season than late? Do they occur chiefly upon the tip of the shoot, or along its entire length? Suggestions as to the significance

of these variant leaves may be found in "The Survival of the Unlike," Essay III.

136. Red cedar (or savin) foliage is peculiar. If the pupil examines young trees and vigorous shoots, he will find the type of foliage shown in Fig. 121. These leaves suggest the foliage of the spruces and firs.

Fig. 122 is from the same tree, and represents a bit of a short branchy growth, such as occurs when the tree begins to bear seeds. The main stem, in the figure, bears the awl-shaped leaves, from the axils of which branches arise



FIG. 123.

Foliage of the old-fashioned tomatoes.

which bear appressed scale-like leaves. The pupil may now examine the common retinosporas, or Japanese arbor vitæ, of gardens; also the common arbor vitæ, or so-called white cedar. He will come to the conclusion that these differences are not incidental variations (that is, not due to

local or transient conditions), but are a distinct and habitual feature of the tree. In other words, some plants normally bear two kinds of leaves.



FIG. 124.

Foliage of ordinary tomatoes.

137. The pupil has already been directed (Obs. xvii.) to a study of the leaves of tomatoes. The accompanying illustrations (Figs. 123-126) will

aid him. Notice the small and curled involute foliage in Fig. 123, which may be found in some of the old-fashioned cornered or "rough" tomatoes like General Grant and Tom Thumb; the large and plane foliage of Fig. 124, which is that of the commonest varieties; the very large foliage, with fewer and nearly entire leaflets, of the Mikado and Potato-leaf varieties (Fig. 125; also, shown in Fig. 90); and the short, stiff and curly foliage of the French Upright tomato (Fig. 126). These types of foliage are characteristic of certain types or varieties of tomatoes, just as the forms of leaves are characteristic of the apple tree and the pear tree; but, as a matter of history, all these varieties are known to have come from one type of tomato within a hundred years. Thus we have another proof that the forms and sizes



FIG. 125.

Foliage of Mikado tomato.

of leaves are not necessarily fixed or invariable.
(See Obs. lvii.)

138. The leaves of various chrysanthemum-like



FIG. 126.

Foliage of French Upright or Tree tomato.

plants are shown in Figs. 127-130. Fig. 127 is the common chrysanthemum of the florists (from Japan). The leaf is strongly lobed. Fig. 128 is a closely related plant, the feverfew of old gardens

(from Europe). Here the same kind of division has proceeded further, so that the leaf is divided; and the divisions are cut and lobed. Fig. 129 is a leaf of the marguerite or Paris daisy of the greenhouses (from the Canaries). Here the same



FIG. 127.

Leaf of common chrysanthemum.



FIG. 128.

Leaf of feverfew.

type of division has taken place, but the blade has become reduced in area. Finally, Fig. 130 is a leaf of the blue-leaved marguerite (also from the Canaries), in which the division has gone still further, and the blade has been reduced to little more than expanded leaf-ribs. If all the tomatoes

(Figs. 123-126) are known to have come from one type of ancestor, is there not reason for inquiring if the ancestors of these very unlike plants may not have been more closely related than the



FIG. 129.

Leaf of common marguerite.



FIG. 130.

Leaf of blue-leaved marguerite.

present forms are? Or, similar types or directions of variation suggest community of origin.

SUGGESTIONS.—Is there variation in the veining and serration, or dentation, of leaves on the same plant? How great may be the variation in size? Do all the leaves on any plant mature at the same time? Is there always the same number of leaflets in the same kind of compound leaves? The pupil should examine the honey locust and Kentucky coffee-tree; and he may have searched for "four-leaved clover."

PART III

STUDIES OF FLOWERS

XXIII. WHAT IS A FLOWER?

139. A flower of the hepatica, or liverwort, which springs from the mold with the first



FIG. 131.

Flower of hepatica.

warmth of spring, is drawn in Fig. 131. The most hasty observation shows that it has several parts. Let us pull them away. We first find three green leaf-like members. Above these are several (seven in this case) pink or blue members. On the inside are about twenty hair-like bodies with pinkish enlargements on their ends, and each of these knobs seems to have two parts. Still inside, is a head of many greenish and pointed bodies. We know that the whole thing is a flower, but we are uncertain as to what

parts are most essential to it. A flower is obviously a more complex structure than a leaf.

140. A week or two later the flower has gone, and a structure like that in Fig. 132 has appeared in its place. We know that in the center of this structure are the seeds. We know, also, that the three green leaves will soon perish, as the other parts have perished, and only the little plants which spring from the seeds will bear testimony that there has been a flower. In other words, the purpose of a flower is to produce seeds, by which the plant is perpetuated.



FIG. 132.

After the flower is gone.

141. If the above conclusion is true, it follows that the most essential or necessary parts of the flower are those which are directly concerned in the production of seeds. These parts, in the hepatica at least, are the very central organs. It is evident, therefore, that if we are properly to understand the flower, we must begin at the center, not at the outside.

142. A flower of the common mustard is shown in Fig. 133. Secure a flower, and count the parts. The details (less half of the enveloping leaf-like parts) are displayed in Fig. 134. The central part, *o*, is to make the seed-pod. The minia-

ture seeds can be plainly distinguished if the part is held to the light. The mature seed-pod is shown in Fig. 135. This has grown to be so unlike the part *o*, that it is scarcely recognizable as the same member. It is necessary, therefore, for purposes of definition, to give the part, as it



FIG. 133.

Flower of mustard.



FIG. 134.

Details of mustard flower.

stands in the flower, a designative name. It is called the pistil.

143. This pistil is plainly of three parts,—the lowest and largest part, which bears the seeds, and which, therefore, we will call the ovary (or "egg-case"); the globular portion at the top, or the stigma (that is, a "mark" or "brand," in reference to its shape); the connecting portion, or style (in reference to its slender form).

144. Surrounding the pistil are six slender

bodies with enlargements at the top. Four are shown at 1 1, 4 4, in Fig. 134. The enlargements

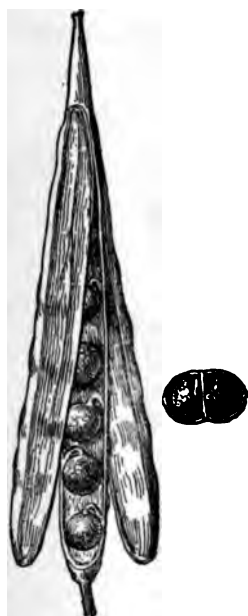


FIG. 135.

The seed-pod of the mustard.

are seen to have two parts, and each part seems to have split along its edge. If the pupil were to rub one of these enlargements upon a bit of black paper, he would probably discover a yellow dust. These slender bodies are the stamens. They are plainly of two parts, the stalk, or filament, and the enlargement, or anther; and the anther contains the yellow powder, or pollen, of which we have spoken.

145. There are two rows of leaf-like parts surrounding the pistil and stamens. These are the floral envelopes, or, collectively, the perianth. The inner row is the colored or showy portion, or corolla. It has four parts, and these we may call the petals. It is suggestive to note the similar forms of the petals and stamens. Both have long stalks (technically called claws in the petals) and a more or less expanded or enlarged portion at the top (the limb, in the petals).

146. The outer row of the floral envelope or perianth comprises four smaller and greenish parts, which, individually, are known as sepals, and collectively as calyx. The calyx, corolla and stamens fall away and perish; and only the pistil matures into another member.

XXIV. WHAT IS A FLOWER? CONCLUDED

147. If the pupil were to cut off the anthers before they open and discharge the pollen, and were then to cover the flower with a paper bag, or were to remove all other mustard flowers from the neighborhood, the pistil would soon die and fall. No seeds would be borne. It is, therefore, certain that the pollen is in some intimate way associated with the production of the seed.

148. If, however, having done this, the pupil were to bring pollen from another mustard flower and deposit it upon the stigma, he would find the pistil maturing and the seeds forming, as if he had not interfered with the flower. It is evident, therefore, that the office of the pollen is to cause production of seed by some action which it exerts after it is applied to the pistil. This action upon the forming seed is known as fertilization; and the transfer of the pollen to the stigma (whether

by the wind, insects, or by man) is pollination. There is a certain time when the stigma is receptive, or ready to receive pollen, and this condi-



FIG. 136.

Pistillate flowers of willow.



tion comes when the pistil is full grown: the stigma then becomes viscid, or sticky, or much roughened, as if to hold the pollen. We now see that the stamens fall because they have performed their office; and the pistil persists that it may

mature the seeds. Since no seeds could be produced without the joint action of pistil and stamens, these members are known as the essential organs of the flower.

149. If the pupil were carefully to remove the petals and sepals, and were then to apply the pollen to the stigma, the pistil might mature and good seeds form. It is evident, then, that the floral envelopes do not hold the most vital relation to the office or purpose of the flower. They are not necessarily essential to it.

150. It so happens that in the greater number of plants the pistils and stamens in any flower mature at different times. That is, the pollen may all be discharged before the stigma is receptive, or the stigma may shrivel and die before the anthers open. In other words, there is frequently only a small chance of a flower fertilizing itself. There must be some means, then, of assuring the transfer of pollen. The commonest means are wind and insects. The flower does not need to attract the wind, but it must have some means of letting the insects know where it is. The showy petals are perhaps the sign-boards. At all events, insects may not visit some flowers when the petals are removed, although they are attracted by them when the petals are undisturbed (see 273*b*).

150*a*. This non-concurrence in maturity of the essential organs is known as dichogamy.

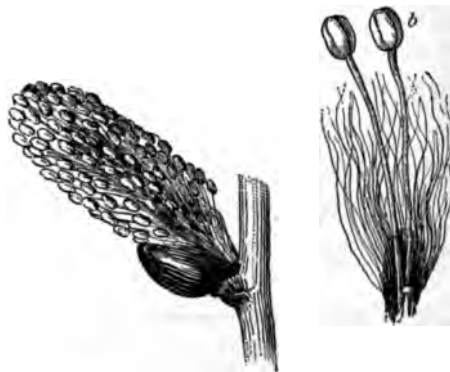


FIG. 137.

Staminate flowers of willow.

151. If the pollen may be carried from flower to flower, it is not essential that every flower

have stamens. Figs. 136 and 137 are the soft bodies which push out from the "pussy willows" in spring. They are really masses of flowers. They are branches, since they are borne in the axil of a bract or scale. The cluster in Fig. 136 has members of a single kind, *a*; and these are clearly pistils, since they bear an ovary and have no pollen (no anthers). The cluster in Fig. 137 also has members of a single kind, *b*, but they are unlike the members of Fig. 136. They are stamens, as may be determined by the pollen and the filaments, and the absence of ovary. In both cases, the parts have no envelopes, but are borne in the axil of a hairy or woolly scale; and it is this silky wool which gives the name of "pussy willow" to the plant. Such flowers are said to be imperfect, because they have only stamens or pistils, in distinction to the perfect flowers, which have both stamens and pistils.

152. What, then, is a flower? It is essentially only a pistil or a stamen.

152a. Since the flower may have two kinds of envelopes—and two kinds of essential organs—it is commonly said that the complete flower is one which has all of these parts, and an incomplete flower is one in which one or more of the series is missing; but this is only a method of stating one's habit of thinking about a flower, and it may lead the beginner to think that there is some necessary or typical plan of flower from which most flowers are deviations. It would be better to drop the terms complete and incomplete, and to say that

flowers which have all the four parts are quadriserial; those lacking only the calyx are triserial; those lacking the floral envelopes are biserial; and those which contain only the pistil are uniserial.

152*b*. It is customary, however, to speak of flowers which lack the calyx as asepalous; and of those which lack the corolla as apetalous. When flowers lack both the calyx and corolla (as the willows), they are said to be naked, or achlamydeous.

152*c*. Flowers which contain pistils and no stamens are said to be pistillate, or fertile. Those which have stamens and no pistils are staminate, or sterile. In common language they are sometimes said to be female and male, respectively, but the former terms are better when speaking of the parts as facts (or as members), without reference to sexuality. When pistillate or staminate flowers are spoken of without designating which they are, they are properly said to be diclinous; which is essentially the same as to say that they are imperfect, as this term is generally used. They are sometimes said, also, to be unisexual, in distinction to bisexual or hermaphrodite flowers (which have both stamens and pistils).

152*d*. When speaking of the staminate portion alone, it is customary to call it the andræcium; and to call the pistillate portion the gynæceum.

SUGGESTION.—The pupil should now have practice in distinguishing the members or parts of flowers, and in interpreting the unusual or disguised parts.

XXV. THE PARTS OF THE PISTIL

153. The pistils of hepatica, mustard, tulip (Fig. 138), and willows are composed of a single straight column. The mustard and willow have a distinct style, but the hepatica and tulip differ in having none. That is, the stigma is often sessile on the ovary, from which we

conclude that while the ovary and stigma are essential to a pistil, the style is not.

154. In all the flowers which we have so far examined the style is single; that is, there is only one straight style on each ovary. In the apple, however (Fig. 139), the styles are five, while the ovary is but one. The pupil should now examine any flowers which he meets, with respect to the absence or presence of styles and to their number; and he will find variations from none whatever to several, or even many, to a single ovary.



FIG. 138.

Flowers of tulip.

155. In the hepatica, mustard and apple, the stigma is one for each style; in the tulip there are three stigmas (or at least three parts to one stigma); in the willow there are two stigmas, and each is again two-parted, and in the catnip (Fig.

140) there are two. These stigmas differ not only in number, but in size and shape. We conclude,



FIG. 139.

Flowers of the apple.

therefore, that stigmas
acteristic forms, as

156. If we examine
tard (o, Fig. 134), we
comprises two distinct
seeds in each. The
enlarged in the ma-
show their character
are borne inside the
true of most plants),
compartments which we

have peculiar and char-
styles do.

the pistil of the mus-
observe that the ovary
compartments, with
parts are sufficiently
ture pod (Fig. 135) to
well. The seeds, then,
ovary (and this is
in distinct cavities or
may call locules.

156a. The compartments of
cells, but this is a common-
has prior use in general lit-
in botanical writings, it should,
signate the ultimate structural



FIG. 140.

Pistil of
catnip.

ovaries are commonly called
language word, and therefore
erature. If it is used at all
perhaps, be restricted to des-
elements or units of the plant,

as employed by anatomists and physiologists. Locule is anglicized from *loculus*, diminutive of Latin *locus*, "a place."



FIG. 141.

Ripened
pistil of
hepatica.

157. In the hepatica (Figs. 131, 132), there are several distinct pistils in a head. Each one contains but a single locule, and ripens but a single seed (Fig. 141). The pistil of the tulip, however (Fig. 142), has three locules, corresponding to as many sides or angles. Pistils contain different numbers of locules, according to the kind of plant of which they are a part.



FIG. 142.

Cross-section of
ovary of tulip.

157a. Pistils with one locule are unilocular or 1-loculed; those with two are bilocular or 2-loculed; those with three, trilocular or 3-loculed; those with four, quadrilocular or 4-loculed; those with five, quinquelocular, or 5-loculed; those with several or many, multilocular, or ∞ -loculed.

158. The ovary is not only variously divided into compartments, but the ovules (or bodies which mature into seeds) are attached to different parts of the locule. In the mustard they are attached to the central partition of the ovary, in the tulip to the interior walls of the locules, in the corn-cockle (Fig. 143) to a columnar central portion, and in the plum (Fig. 144, o) to the outward side of the locule. In general, there is a more or less distinct elevation or thickening of tissue at the

place where the ovules are attached. This is emphatically shown in the fruit of the May-apple or mandrake (shown in cross-section in Fig. 145). This point of attachment is known as the placenta (plural, placentæ).

158a. The placenta is defined with reference to its position. It is evident that there are two general types of placentæ,—those which are borne upon the outward walls of the ovary, and are called parietal, and those that are borne in the center, and are called axile. Of the axile placentæ, there are two kinds, those which are attached to the partitions or dissepiments of the ovary (as in the tulip, Fig. 142), and those which are borne upon a separate central column, and are, therefore, called free axile placentæ (as in the cockle, Fig. 143, and in all the pink tribe, as the pinks, carnations, chick-weeds, catchflies; and also in the primroses).

159. It is now seen that the pistil is not



FIG. 143.

Free axile placenta of corn-cockle.

always the simple structure which it looks to be from the outside. That is, it may be either simple



FIG. 144.

Flowers of plum.

or compound. A compound pistil is one which bears evidence of containing two or more united parts or units. The common test of a compound pistil is the presence of more than one locule,

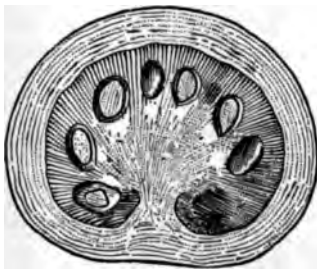


FIG. 145.

Large parietal placenta of
may-apple.

but this is not always designative, for in some cases false partitions grow out from the walls into the cavity of the ovary. The presence of more than one style to a single ovary also indicates a compound pistil; and, more especially, the occurrence of more than one placenta. The separable

units or parts in a compound pistil are known as carpels. The theory of a compound pistil is that

it is made up of the union of two or more simple pistils.

159a. Thus the hepatica has one carpel, the tulip has three, the mustard has two, the catnip has two 2-lobed carpels, the apple has five, and even the unilocular cockle (Fig. 143) is thought to be 5-carpelled because of the five styles (two being cut away in the figure) and of certain peculiarities in related plants;—that is, there is evidence that some plants which were once 5-loculed are now 1-loculed because of the loss of partitions; and sometimes this elision can be traced in the different ovaries of a single plant.

159b. A flower, therefore, may contain one simple pistil, several simple pistils, or one compound pistil; and there are instances in which it contains more than one compound pistil.

SUGGESTIONS.—When taking up any unfamiliar flower, look first for the pistil. The ovary is the best distinguishing mark, for the pistil is often much disguised. Determine what relation exists between the numbers of stigmas, styles, or locules in any pistil. Also observe the number of ovules, and the placenta.

XXVI. THE STAMENS

160. The most striking feature of the stamens in the flowers which we have seen is the great difference in length and shape. Most of the stamens are slender, and have prominent stalks or filaments; but the anthers of the currant (Fig. 146) are nearly sessile, and in some flowers they are completely sessile. It is, therefore,

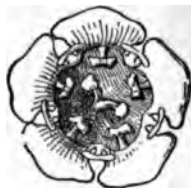


FIG. 146.
Flower of garden
currant.

apparent that a filament is not essential to a stamen any more than a petiole is essential to a leaf.

161. All these anthers appear (so far as we can see) to contain more than one cavity. Most of them apparently have two compartments; and this is the general rule. It is easy to ascertain that these compartments (which



FIG. 148.

Flower of wild lily.

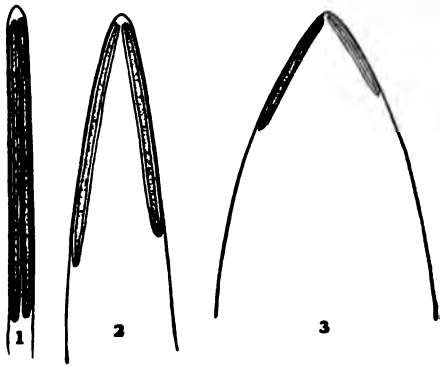


FIG. 147.

Stamens of water lily.

we shall call locules) contain the pollen (144).

161a. It is the custom to call the anther compartment a cell, but this word should be other-

wise employed (156a). As no confusion has arisen from the application of the word cell to both pistils and stamens, none may be anticipated from a like use of locule. It has been suggested

to use *locellus* (diminutive of *loculus*) for the anther compartment, but it seems to be unnecessary to introduce another word, and, moreover, *locellus* has no accepted anglicized form (although it might be shortened to *locel*).

162. The anther of the tulip and willow is attached by the base to the very top of the filament, but that of the water-lily (Fig. 147) seems to be joined to the filament in its entire length. The mustard and the lily (Fig. 148) show still a third method, the anther being poised by attachment to its back, and standing cross-wise the filament. These three methods, with numerous intergradations, will impress the pupil, if he were to examine numbers of flowers, as being the types of the ways in which the anther is borne upon the filament.



FIG. 149.

Pores in
azalea
stamen.



FIG. 150.

Sensitive stamens of barberry, showing a single flower, and the dehiscence of the anthers at *a* and *d*.

162a. These modes may be called, respectively, the innate (attached at base), adnate (attached throughout its length), and versatile (attached near the middle, or at least at some distance from the ends).

163. The exposure of the anthers in the mustard and the lily is in opposite directions. The anthers of the mustard

look inward (towards the pistil), or are said to be introrse; those of the lily look outwards, or are extrorse. The pupil should determine if innate and adnate anthers differ in this regard, also.



FIG. 151.

FIG. 152.

FIG. 153.

Flower of scarlet sage.

Carnation flower.

Tell-tale flower of hepatica.

164. The anthers of the mustard and the tulip seem to open along the side of each locule. The azalea, however (Fig. 149), opens by a hole or pore in the tip of the locule. Heaths and huckleberries open in the same way. We should examine

the barberry (Fig. 150), in which the anther opens by means of a lid.

164a. The barberry flowers are honey-sweet, and attract the bees; and the plant seems to make the most of its opportunity. When the flowers are just expanded, and the sun is warm, touch the filaments upon their inner side with a pin or point of a pencil. See what happens. Observe, also, the curious way in which the anthers open. The pupil will now be interested in the anthers of other plants of this family, such as may-apple, jeffersonia, and blue cohosh.

164b. The opening of any closed organ is known as its dehiscence. We have found, then, that the dehiscence of the anther locules is various, and that it follows at least three types or methods.

165. We have seen that there are commonly two locules, and in the water-lily (Fig. 147) they are separated by the width of the filament. A flower of the scarlet sage of gardens and green-houses is laid open in Fig. 151. The anthers are at 1 and 2; but a closer examination of the anther shows that it has but a single locule, and as other mints have two, we are suspicious that the other compartment has been lost. The truth is that in some kinds of sage (as the common garden sage) the two locules are separated by a stalk or bar, which runs crosswise the top of the filament. This bar, separating the two locules of an anther, is called a connective. In the flower before us, the other locule has apparently vanished in the process of time, and the places where we should expect to find it are at 3 and 4, on

the other end of the connective. We have, then, still a fourth kind of anther-bearing, but it is clearly a special case of versatile arrangement; that is, it is not a general type or mode.

SUGGESTIONS.—The presence of pollen is the one infallible proof of stamens. The pollen is commonly in the form of yellow grains, and is easily recognized even by the naked eye. In identifying stamens, note first the form and dehiscence of the anther, then the position of the stamen with reference to other parts of the flower. Find the stamens of the apple, rose, strawberry, carnation, lily, crocus, lilac, honeysuckle, verbena, orange, fuchsia, geranium.

XXVII. THE INSERTION OF THE FLOWER

166. We have discovered (Obs. xx.) that there are several ways in which the petiole is attached to its support. In the mustard (Fig. 134), all the parts of the flower are inserted at or near a common point, which is really the end of the flower-stalk. Since so many parts are attached at this place, the area becomes enlarged, and it projects laterally beyond the base of the ovary. This expanded end of the flower-stalk, or the flower-seat, is known as the receptacle or torus.

167. It is further observable that all the parts of the mustard flower are separate; or, in botanical language, the members are "free and distinct,"—free when they are not combined with (or joined

to) parts of another set, and distinct when the members of any series are not united with each other.

168. The apple is not so (Fig. 139). There is no obvious receptacle, but the stalk seems to grow directly into the flower. More than that, the parts of the flower are not free and distinct, for the five carpels (as indicated by the five styles) are grown into one compound ovary, the sepals seem to be attached to this ovary, and the stamens to be borne on the very lowermost part of the sepals. (See Obs. lv.) It is evident, then, that the parts of flowers may be variously consolidated; and it is apparent, also, that the insertion of the flower may be simple, as in the mustard (the parts all borne upon a distinct receptacle), or it may be complex (the parts variously superposed upon each other).

169. There are, then, two more or less distinct positions of the ovary with reference to the insertion of the other parts,—either the ovary may be superior (free from the other parts, and, therefore, inserted above them, or wholly inside the flower), as in the mustard, or it may be inferior, as in the apple (the other parts, or some of them, borne upon it).

170. The insertion of the flower may also be expressed in terms of the other series, as well as in terms of the pistil. Instead of saying that the ovary is inferior in the apple, we might say that

the other parts are superior. It is better, however, to speak in terms of the ovary; and there are three grades of insertion of the parts recognized in botanical writings. When all the parts are free, the flower is said to be hypogynous (parts inserted below the pistil), as in the mustard and hepatica. When the stamens and petals are borne on the calyx, and the calyx is wholly or partly free from the pistil, the flower is perigynous (parts inserted around the pistil, but not upon it nor upon the receptacle.) The plum and cherry (Fig. 144) have been considered to be typical examples of perigynous flowers, but many botanists now hold that the cup of the flower is a hollow receptacle and not a calyx-tube, and that the sepals, petals and stamens are borne upon the receptacle-rim. When all the parts seem to rise from the top of the ovary itself, the flower is epigynous (parts on the pistil).

SUGGESTIONS.—Notice begonias, fuchsias, carnations, buttercups, potatoes, currants, pinks, lilies, blue-flags or irises, narcissuses, and pumpkins or squashes.

XXVIII. REINFORCED FLOWERS

171. A section of a carnation flower is shown in Fig. 152. The notched corolla is prominent at the top, and the calyx is at *b*, but there are other

series of green calyx-like parts at *c* and *d*. There is no precedent for calling these last a part of the calyx; moreover, they seem to grade off into bracts and normal leaves. They (*c* and *d*) really are bracts or reduced leaves. Let the pupil examine the flower of the strawberry, and answer what is calyx and what is bract; or he may look at the "hull" of the ripe strawberry. It is often difficult to determine where leaves end and where flowers begin.

172. We saw the hepatica in Fig. 131, and probably counted a row of petals and a row of sepals. Now and then we come upon a flower like that in Fig. 153, in which this supposed calyx is distinctly separated from the rest of the flower. We are suspicious that this may not be a calyx after all. We then examine the near relatives of the hepatica—like the anemones, or wind-flowers—and find that they have only one series of floral envelopes, and some of them have three distinct bracts or leaves upon the stem. Furthermore, these supposed sepals are only three, while the supposed petals are five or more. This also raises a doubt as to whether both series are parts of the flower, for the calyx and corolla are usually of the same number of parts, or one a multiple of the other. We must conclude, therefore, that these three leaves are only bracts, not sepals.

173. Having disposed of the three bracts, we now ask if the colored parts above them are sepals or petals. There is nothing in the flower



FIG. 154.

Flowers of the flowering-dogwood.

to help us in answering the question; we therefore follow the custom of botanists, and say that when either floral envelope is wanting, it is the corolla (unless there is some special reason to the contrary). This is, generally, an arbitrary definition,

but it would be just as arbitrary to say that the sepals are missing.

174. Most persons are familiar with the flowering-dogwood, the small twisted-grained tree which hangs its pink-white sprays against the woodlands in early spring. Fig. 154 will identify it at once. It appears to have four great petals, and a cluster of essential organs in the center. If one of these central parts is examined, however, it is seen to have a corolla of its own, with stamens and a pistil, and each produces a seed. The great "flower," then, is a cluster of inconspicuous flowers and a circle of petal-like bracts. These encircling bracts, whether of the dogwood, hepatica, or strawberry, constitute an involucre. This involucre may reinforce either a single flower or a flower-cluster.

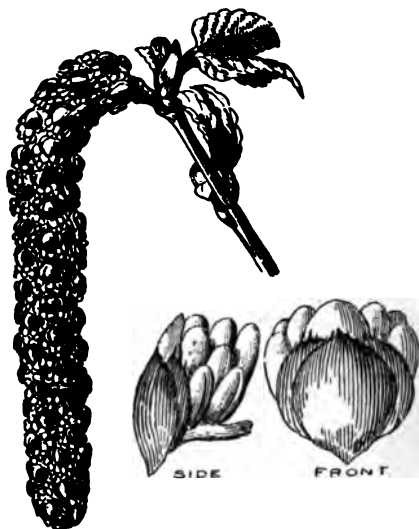


FIG. 155.

Staminate catkin of paper birch.

175. If the flower is borne upon the end of an

ordinary stem, and if it is sometimes a matter of definition to determine what are bracts and what are floral envelopes, we begin to wonder if flowers are so very much different from other parts of the plant, after all. The lesson to be derived from this discussion is not what particular interpretation has been placed upon certain facts, but that there is endless variety, and that every fact and phenomenon must be investigated for itself; and there is sometimes a gradation from leaves to flowers.

SUGGESTIONS.—Involucres and bracts may answer the purpose of petals. It would interest the student to find colored leaves upon flower stems. Let him ask a florist for a plant of the scarlet sage or the poinsettia; or he may grow the sclarea, seeds of which can be obtained of seedsmen. The wild flowers known as painted-cup (*castilleja*) have very conspicuous, colored bracts or leaves. The pupil will now be interested in tracing resemblances between leaves and the parts of the perianth.

XXIX. DICLINOUS FLOWERS

176. We have seen that many flowers have not both stamens and pistils. The willow is such a case (Figs. 136, 137). The willow is also peculiar in the fact that the flowers are borne in a dense elongated scaly cluster. Such clusters of flowers are called aments or catkins.

176a. It is customary to speak of staminate and pistillate plants as two sexes; but sex in plants may not be comparable with sex in animals.

177. The staminate catkin of one of the birches is shown in Fig. 155. This is a drooping body, and recalls the similar tassels of the poplars, oaks, and hazels. In this instance, however, there is more than a single flower beneath each scale of the catkin. In other words, a catkin may be either simple (comprising a single flower at each joint or under each scale) or compound.

177a. There are commonly three beneath each external scale in the birch, each flower comprising two stamens, but the anther locules are separated and the filaments divided so as to imitate four stamens. These flowers are separately subtended by bractlets.

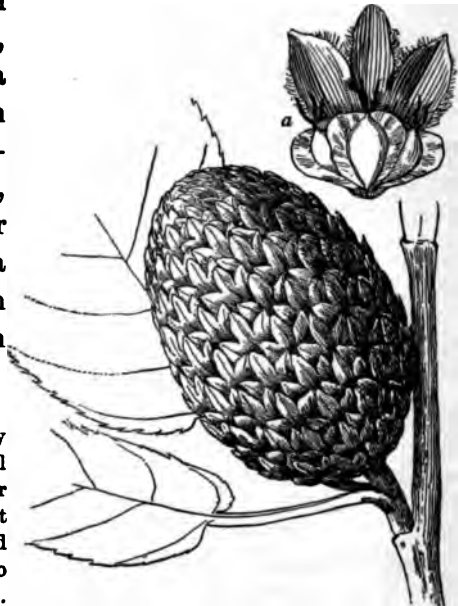


FIG. 156.

Pistillate catkin of a birch.

178. The pistillate catkin of another kind of birch is shown in Fig. 156. It is a rigid or erect structure, and, of course, persists until the seeds are ripe, whereas the entire staminate catkin very soon dies and falls. One of the three-parted bracts or scales is removed and reversed at *a*. It sub-

tends three naked pistils, each having two styles and being provided with a broad wing. It is seen, therefore, that staminate and pistillate catkins



FIG. 157.
Pistillate catkin of
blue-beech.



FIG. 158.
Winter catkins of
filbert.



FIG. 159.
Pistillate flowers
of hazel.

may be very unlike in form and appearance; and this may be true in the catkins of the same kind of plant.

178a. The pupil will now be interested in the structure of the flower-clusters of the blue-beech or hornbeam. A pistillate catkin is shown in Fig. 157. The three-lobed bracts suggest the birch, but the catkin is so loose and open, and the bracts become so green and leaf-like, that the part would scarcely pass for a catkin,—affording another illustration of the endless variety and in-



FIG. 160.

Inflorescence of the small-fruited hickory.



FIG. 161.

Staminate flower of Hubbard squash.

formality in plants, and also of the essentially leaf-like nature of bracts and scales.

179. If one were to examine the bushes of hazel (or the cultivated



FIG. 162.

Pistillate flower of Hubbard squash.

filbert), in the winter, he would probably find objects like those in Fig. 158. These are the staminate catkins in bud, so to speak. That is, they are formed in the fall (as buds are; see 45), but remain short, compact and rigid. With the first warmth of

spring they lengthen and dangle in the wind, discharging showers of pollen. The resemblance between catkins and ordinary branches is, therefore, very close, since each of them may constitute a winter bud and each bears scales (or reduced leaf-like bodies), from the axils of which flowers arise.

180. When the staminate catkins of the hazel are hanging on the twigs, the pupil may be looking in vain for the pistillate flowers. He may discover them by means of the red stigmas which are thrust from the buds, waiting for the wind to bring the pollen their way. These stigmas are seen protruding from the two lower buds in Fig. 159. Each flower has a single ovary and two styles; the pupil may count how many flowers there are in the bud. If one of the sexes is in a catkin, it is not necessary that the other shall be.

180a. The pupil will now examine the oaks, in which the staminate flowers are in catkins, but the pistillate flowers (which produce the acorns) are not. In the beech the staminate flowers are in pendulous heads (which are a kind of catkin), but the pistillate flowers are mostly in pairs upon a short stalk. The student should determine how the flowers of the chestnuts are borne. Examine the plane-tree (buttonwood or sycamore).

181. A spray of hickory (sometimes called "white walnut" in the East) is shown in Fig. 160. The staminate catkins are borne about three together from a single stem (at A), and they arise directly from the terminal winter bud. When these catkins

are pushing out, the young shoot is growing rapidly, and it makes a little cluster of pistillate flowers at its end (S); and these pistillate flowers appear in season to receive the benefits of the pollen. In the hickory, then, the fruit-buds are both terminal and co-terminal (55).

181a. Is not the birch catkin, Fig. 156, co-terminal? The pupil may now revert to the discussion of Fig. 55, and to an examination of the fruit-bearing of hickories and walnuts.

181b. We have seen, then, that those flowers which are borne in catkins or aments are diclinous (152c); and this is usually the case. The true catkin-bearers or amentaceous plants, in fact, are always diclinous. These comprise all the oaks, chestnuts, hazels, willows, poplars, birches, alders, beeches, hornbeams, walnuts and hickories; and these are for the most part very early-flowering trees or bushes. The fruits of many of them are nut-like.

182. It is evident that the catkin is only one kind of a flower-cluster; and as we shall so often need a comprehensive term to designate the mode of flower arrangement, we shall hereafter use the word inflorescence. (See Obs. xxxv. and xxxvi.)

183. Since flower-clusters often branch, we cannot use the word peduncle (or flower-stalk) indiscriminately. We use it for the flower-stem, when the cluster is simple or unbranched; but when the cluster is branched, we use it for the stem of the entire cluster, while the particular stalklet upon which the flower is borne is called the pedicel.

183a. Thus, the stem of the hepatica (Fig. 131) is a peduncle; the main stem of the so-called flower of the dogwood (Fig. 154) is



FIG. 163.

Diclinous flowers of the cucumber.

a peduncle, and the real flowers are sessile; the staminate catkins of the hickory (Fig. 160) are upon very short pedicels, three catkins springing from one peduncle.

SUGGESTIONS.—Let the pupil determine whether the poplars, cottonwoods and willows which he passes on the streets are staminate or pistillate, and if there is any difference in habit between the sexes. Of the weeping willow and Lombardy poplar (which are foreign trees), only one sex has been introduced into this country. Which one is it? Why do strawberry-growers plant different varieties together?

XXX. DICLINOUS FLOWERS, CONTINUED

184. The squashes and pumpkins send up yellow, bell-like flowers on long, slender stalks all during the summer months, but these flowers soon

with. One of them is seen in Fig. 161. It is a staminate flower, and its normal course is to live for a day and perish. Hidden under the foliage, on short stems, are flowers like that shown in Fig. 162. The ovary (or young squash) is seen below the flower-cup. It is, therefore, a pistillate flower, and the ovary is inferior.

184a. The pupil should now examine flowers of any cucurbitous plants,—those of pumpkins, squashes, gourds, cucumbers, melons, and the like. Figs. 163 and 164 show other members of this family or tribe. Let the pupil designate the staminate and pistillate flowers in these pictures. It is seen that the staminate flowers are not long-peduncled in all of them. Now count the number of staminate and pistillate flowers produced on any vine, and deter-

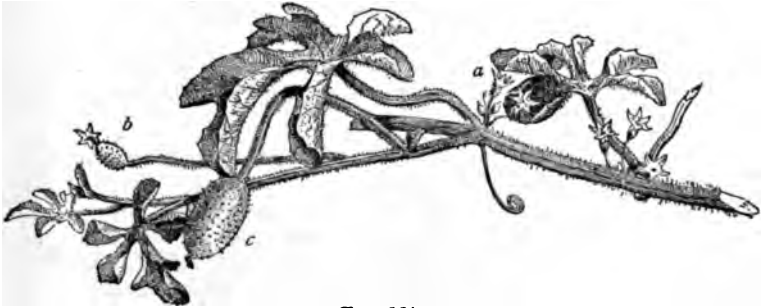


FIG. 164.

Flowers of the bur-cucumber or gherkin.

mine if they maintain the same proportion to each other throughout the season. Note the hour of the day at which they open. Determine if the flowers close, and if they ever open again.

185. The sedges or carices are grass-like plants which grow in low places (although some of them

are dry-soil plants). They are very common, and generally comprise a large bulk of "bog hay." They blossom in early spring. One of them is shown in Fig. 165. The stamens are at *a*, for the anthers can be plainly distinguished, and the pollen discharges freely. A dense, simple (that is, unbranched) inflorescence, in which the individual flowers are sessile, or very nearly so, and which is more or less elongated, like these flower-clusters in the sedge, is known as a spike.

185*a*. Spike is a generic or general term. Catkin is a particular kind of spike. If a spike-like inflorescence were shortened to be about as broad as long, it would be called a head, or capitulum.

186. The three spikes at *b b b*, in Fig. 165, are pistillate. The two stigmas protruding from under each scale show the location of the flowers (but the flowers of some sedges have three stigmas). The il-



Fig. 165.

Flowers of carex or sedge.

lustration at Fig. 166 represents another common sedge. In this case, however, the two kinds of flowers are not in separate spikes. The spikes are all short and head-like, and the stamens are hanging at the base of each spike (*a*), and the



FIG. 166.

Flowers of a *Carex*.

pistils occupy the upper portion of the same spike. The lower spikes are subtended by long, leaf-like bracts, *b b*, showing a gradation into the normal foliage of the plant. Since we cannot speak of each spike in Fig. 166 as either staminate or pistillate, we must use a special term for it; we shall, therefore, call the spike androgynous (containing both staminate and pistillate flowers).

187. An ear of corn is shown in Fig. 167. The husks are stripped back to show the kernels. If the pupil were to search ever so diligently he could not find stamens. Are there any flowers whatever on the ear? The ear produces seeds; therefore there must be flowers.

188. Is the entire ear a single flower with many pistils (we have

seen that a single hepatica flower has several pistils), or are there many flowers in a dense spike? This question is really very difficult for a beginner to answer. We know, in the first place, that the flower—wherever it is—must be diclinous, for we can find no evidence of stamens. We know, too, that each young kernel of corn is part of a pistil, because it ripens a seed. If it is a pistil, then the "silk" is the style. The husk is very unlike a perianth. We must conclude that an ear of corn is a spike of flowers, the cob is the rachis of the spike, the silks are the styles, and the husks are the involucre of the spike.



FIG. 167.

Pistillate flowers of Indian corn.

SUGGESTIONS.—The pupil will now have a dozen questions to ask about corn; and he should go to the corn plant for answers. Where are the staminate flowers? What are the "tassels"? What

is the dust which irritates the eyes of the workman when the corn is in full tassel? Is there one silk, and only one, to each kernel? Are there always a definite number of rows of kernels on each cob? Are the rows in even or odd numbers? Do different ears on the same stalk always have the same number of rows? Having found the staminate flowers, determine if the plant is dichogamous.

XXXI. DICLINOUS FLOWERS, CONCLUDED

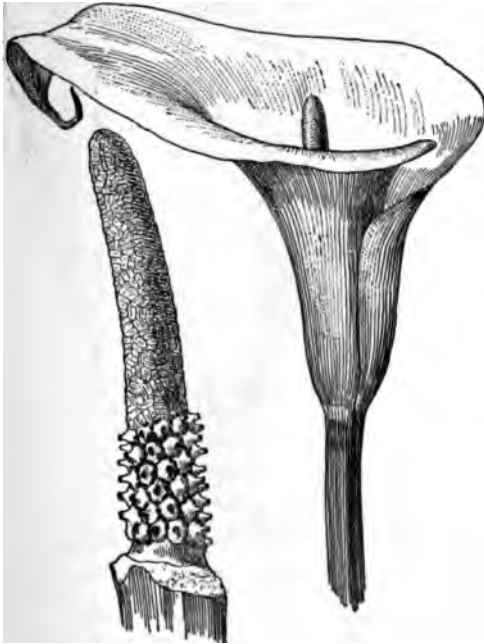


FIG. 168.

The calla.

189. A calla is shown in Fig. 168. At first glance, it appears like a flower with a single great petal and one pistil; but we have not thus far discovered flowers of one petal, and the form of the part makes us suspicious that the structure must have some special interpretation. We have already found that the proper way in which to understand a flower is to begin at the inside.

190. Tearing away the wax-white part, we have

the central column shown at the left. It has two parts. In the condition in which it is seen in the picture, the lower part is developed, but the upper part is not. Each of the numerous objects on the lower part is found, upon being sectioned, to contain three cavities, which contain ovules. These objects, therefore, are pistils. If the same calla were seen a few days later, the upper part of the spike would be found to be in bloom, but the flowers would comprise only stamens. In other words, the central column in a calla is an androgynous spike, comprising very many flowers.

190a. A noticeable feature of this spike is the great difference in time of maturity of the two kinds of flowers. The spike is strongly dichogamous. In this case, the pistils mature first, whence the plant is said to be proterogynous ("pistils earliest"), but in many other plants the stamens mature first, plant proterandrous ("stamens earliest"), although this condition is less frequent than the other.

191. The flowers of the calla, then, are naked or achlamydeous (152b). The great white portion, which we commonly call the "flower," is only a reinforcement of the spike, the same as the four great bracts reinforce the flower-head of the dogwood (Fig. 154). This particular kind of one-leaved involucre is known as a spathe, and the spike which is inclosed in it is a spadix.

191a. The pupil should now examine the jack-in-the-pulpit (or Indian turnip), the skunk cabbage, and various spadiceous flowers (like the anthuriums) of the greenhouses. Observe the great differ-

ences in the forms of spathes, and that some of them do not encircle the spadix. Explain, also, the great head of red berries which is borne by the jack-in-the-pulpit.

191b. Observe that flowers which are enclosed in corolla-like spathes are usually achlamydeous.

192. In all these studies of diclinous or separated flowers, we have been impressed with the great variety in forms of flowers and in their arrangement. In most of the plants which we have examined the two kinds of flowers are upon the same plant; but in the willows and the poplars and some other plants, the two kinds or sexes are upon different plants, so that one plant is wholly staminate and one wholly pistillate.

192a. When staminate and pistillate flowers are borne on the same plant, the plant is monœcious (word meaning "in one house"). When they are on separate plants the plants are diœcious ("in two houses").

193. In respect to the relative locations of the essential organs, we can now construct a gradation: both kinds of organs in the same flower and maturing simultaneously, or synanthous (uncommon); both in the same flower, but dichogamous (very common); in separate flowers in the same flower-cluster, or androgynous (occasional); in separate clusters on the same plant, or plant monœcious (frequent); upon different plants, plants diœcious (occasional); variously mixed upon the same

plant, flowers polygamous (infrequent; some maples are examples).

SUGGESTIONS.—It is excellent practice to endeavor to find the sexes in dioecious plants. "Pussy" willows are attractive, and they take the pupil into places where he is certain to find interesting things. When the willow catkins are in full bloom (they are not yet fully out when in their "pussy" stage), select as many apparent mates—that is, staminate plants and pistillate plants of the same kind—as possible, mark them with tags, and then visit them when in full leaf, and see how closely you have matched them. In all diclinous plants the pupil should determine if the staminate and pistillate flowers are approximately equal in number.

XXXII. THE DANDELION

194. The first warmth of spring brought the dandelions out of the banks and knolls. They were the first proofs that winter was really going, and we began to listen for the blackbirds and swallows. We loved the bright flowers, for they were so many reflections of the warming sun. They soon became more familiar, and invaded the yards. Then they overran the lawns, and we began to despise them. We hated them because we had made up our minds not to have them, not because they were unlovable. In spite of every effort, we could not get rid of them. Then if we must have them, we decided to love them. Where once were weeds are now golden coins scattered



FIG. 169.

Dandelion.

FIG. 170.

Floret of dandelion.

in the sun, and bees revelling in color; and we are happy!

195. A dandelion is shown in Fig. 169. It is a strange flower, as measured by those which we have already studied. It appears to have a

calyx in two parts or series, and a great number of petals. If we look for the pistils and stamens, however, we find that the supposed simple flower is really complex. Let us pull the flower apart and search for the ovary or seed. We find numerous objects like that in Fig. 170. The young seed is evidently at *e*. There are two styles at *d*, and a ring of five anthers at *b*. The dandelion, therefore, must be composed of very many small and perfect flowers.

196. Looking for the floral envelopes, we find a tube, and a long strap-like part running off to *c*. This must be corolla, for the calyx is represented by a ring of soft

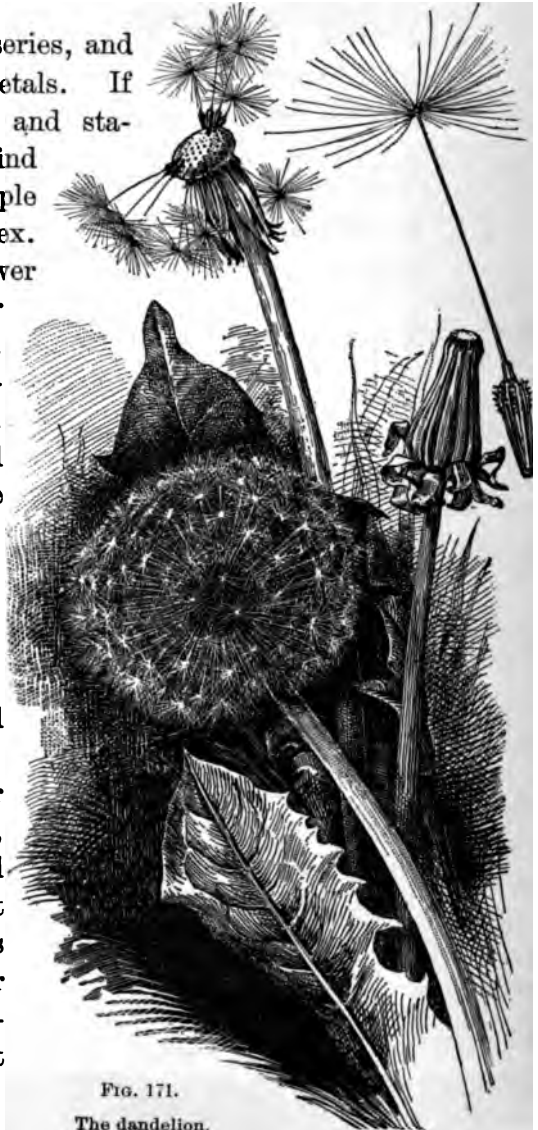


FIG. 171.

The dandelion.

bristles, *a.* We have, then, a head made up of quadriserial flowers, or florets, as the individual flowers may be called. The entire head is reinforced by an involucre, in much the method in which the dogwood is subtended by four petal-like bracts and the calla spadix by a corolla-like spathe.

197. One cloudy morning the dandelions had vanished. A search in the grass revealed numbers of buds, but no blossoms. Then an hour or two of sunshine brought them out, and we learned that flowers often behave differently at different times of the day and in various kinds of weather.

198. In spite of the most persistent work with the lawn mower, the dandelions went to seed profusely. At first, we cut off many of the flower-heads, but as the season advanced they seemed to escape us. They bent their stems upon the ground and raised their heads as high as possible and yet not fall victims to the machine; and presently they shot up their long soft stems and scattered their tiny balloons to the wind, and when the lawn-mower next passed, they were either ripe or too high to be caught by the machine.

199. This seed has behaved strangely in the meantime. The fringe of pappus (as the bristle-like calyx is called) is raised above the seed by

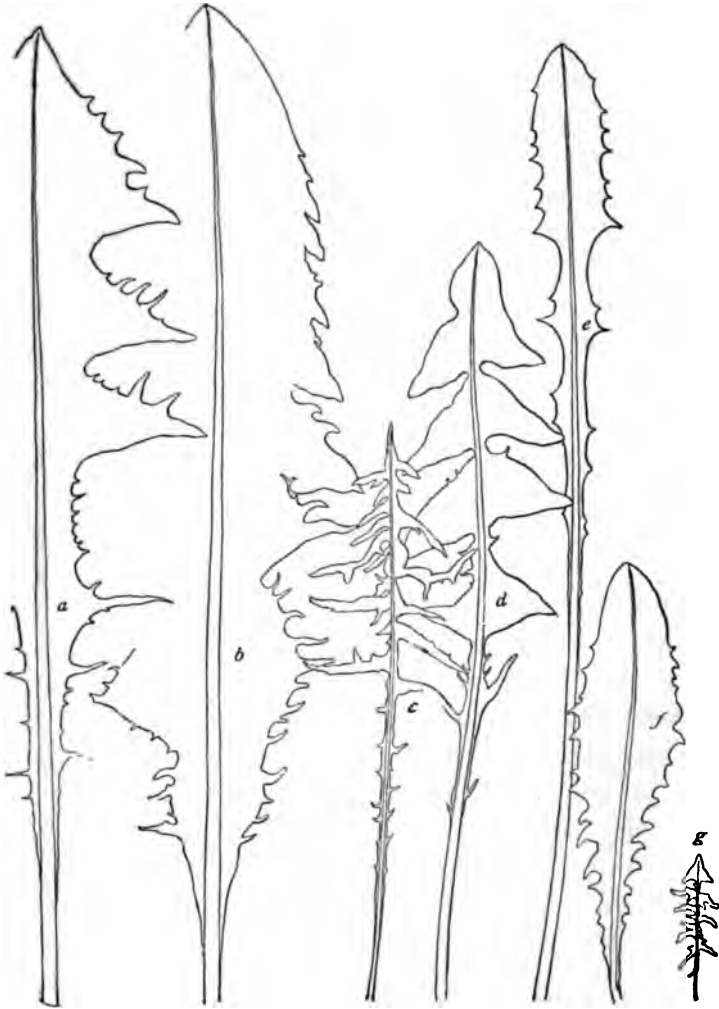


FIG. 172.

Variation in dandelion leaves. All drawn natural size and then reduced one-half.

a short, narrow neck (*e*, Fig. 170), when the plant is in flower; but at seed-time this neck has grown an inch long (Fig. 171), the anthers, styles and corolla have perished, the pappus has grown into a spreading parachute, and the ovary has elongated into a hard, seed-like body. Each one of us has blown the tiny balloons from the white receptacle, and has watched them float away to settle point downwards in the cool grass; but perhaps we had not always associated these balloon voyages with the planting of the dandelion.

200. The dandelion, then, has many curious habits. It belongs to the great class of compositous (or compound) flowers, which, with various forms, comprises about one-tenth of all the flowering plants of the earth. The structure of these plants is so peculiar that a few technical terms must be used to describe them. The entire "flower" is really a head, composed of florets, and surrounded by an involucre. These florets are borne upon a so-called receptacle. The plume-like down upon the seeds is the pappus. The anthers are said to be syngenesious ("in a ring"), because united in a tube about the style; and this structure is the most characteristic feature of compositous flowers,—more designative of them, in fact, than the involucrate head, for in some other kinds of plants the flowers are in such heads, and in

some compositous flowers the florets are reduced to two or three, or even to one!

SUGGESTIONS.—Is the bud at the right in Fig. 171 a flower closed up, or one which has not yet opened? Are the stems of the dandelions which bloom first in the spring shorter than those which bloom later? Do the flowers close at night and in dull weather? How long a period of sunshine is necessary to open the flowers? Does a flower open more than once? Does the head (or involucre) ever close up after it has gone to seed? What time is required for the flower stem to straighten up and to reach its full height? How many rows of bracts or scales are in the involucre? Do the positions of these bracts change from flowering-time to seeding-time? How far may a dandelion seed travel in the wind? Do dandelion plants vary much in size and shape of leaves (compare Fig. 172)? Is the variation associated with vigor of plant, richness and moisture of soil, or other conditions? At what seasons are dandelions most abundant? Do they ever bloom in fall or winter? How long does a dandelion plant live? Upon what kind of soil does it thrive best?

XXXIII. THE COMPOSITOUS TRIBES

201. A rudbeckia, or yellow ox-eye daisy, is a common plant in pastures and meadows. It has rough and hairy stems and leaves. A flower of it is shown in Fig. 173. The central part of the flower is high and cone-shaped, and a cross-section of it shows that the receptacle, *e*, is really a much-shortened stem, with flowers along its side. In other words, the receptacle in compositous flowers is the rachis of a condensed spike, and

is, therefore, unlike the receptacle of single flowers.

202. This flower-head also differs greatly from that of the dandelion, because it has a black-

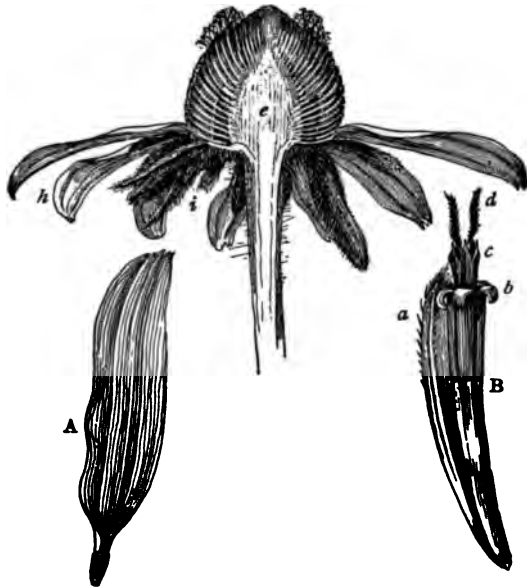


FIG. 173.

Yellow ox-eye or rudbeckia.

brown center and a yellow corolla-like rim, *h*. The green and hairy involucre is readily distinguished below, at *i*. Dissecting the flower, these outer yellow petal-like bodies are found to be like the figure at *A*. This suggests one of the florets of the dandelion, except that it has no essential

organs. The tube-like base, and especially the abortive ovary or seed, show that it is morphologically a flower, but it is neutral! That is, there are some members which bear every evidence of being modified flowers which have no stamens or pistils and which, therefore, are functionally not flowers at all; but they may answer the purpose of the petals of simple flowers in attracting insects.

202a. Neutral flowers are frequent in the composites. Examine the sunflowers, cosmos, and coreopsis (or calliopsis of gardens). In other kinds of plants, neutral flowers may be found in the snow-balls and hydrangeas.

203. These showy florets make a corolla-like rim about the head, like the rays about the sun. In all composites, therefore, these marginal flowers, when present, are known as rays or ray flowers.

204. One of the interior brown flowers is shown at B. This has no ray, but, instead, the corolla is symmetrically five-toothed (*b*), and the stamens (*c*) and styles (*d*) are present. These rayless florets are known as the disc florets, and a head which has no ray flowers is said to be discoid. But plants like the dandelion have no disc florets, for we have seen that all the florets in the head are ray-form or strap-shaped.

204a. In some composites, the ray florets are perfect and in some pistillate; and in a number of kinds the rays are the only perfect-flowered and seed-bearing florets in the head. It is seen, therefore, that even compositous heads may be androgynous.

205. The fact that the corolla of the disc florets is five-toothed may help us to understand what the single ray or strap of the ray florets is.

These rays in both the dandelion and rudbeckia are minutely five-toothed at the end. This suggests that the ray represents the five parts of the corolla, and this is the customary interpretation. It is evident that if the corolla of a floret were to develop to such a length, it could not

spread equally in all directions, as

a mathematical calculation will prove; it therefore develops in one direction, as a leaf does.

206. Another peculiarity of

the rudbeckia, as compared with the dandelion, is the absence of pappus. The pupil should now examine the sunflowers; and he has probably already had experience with the barb-like bristles of the "pitch-forks" or "stick-tights," which collect on the



FIG. 174.

Fuller's teasel. The dry, mature head used for teasing cloth.

clothing in a walk through a weedy field. He will soon be prepared to say that the pappus may be either absent or very abundant, and may vary in character from a narrow rim on the top of the seed-like body to scales, barbs, bristles and plumes.

207. The disc floret in Fig. 173 has another peculiarity in the presence of a scale (*a*). This is present in many compositous flowers, and, like nearly all scales, is homologous with a leaf; one of these scales subtends each floret, and thereby we have another proof that the receptacle of a composite head is really a shortened branch, or a rachis.

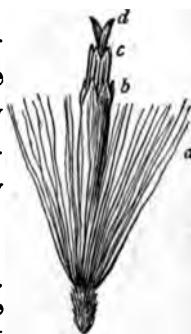


FIG. 175.

Floret of aster.

207*a*. The pupil will now appreciate the teasel. One form of it is common along roadsides in the Eastern states. The flower-head would pass at once for a composite, but the anthers are not syngenesious, and there are other technical differences; so that the teasels are not classed with compositous plants, although closely allied to them. The fuller's teasel (Fig. 174) is remarkable for the enormous development of the scales; and after the flowers have perished, the dry head is used for raising the nap on woolen cloth. The plant is cultivated in central New York for this purpose.

208. Another important contrast of the rudbeckia and the dandelion is to be found in the involucre. In each case the scales or bracts of the involucre are approximately in two rows, but in the rosin-weed the two rows occupy the same position,

whereas in the dandelion the outer row is reflexed. The pupil should now explore the involucre of compositous flowers, noting especially the spiny scales of the thistles, the hooked scales of the burdock and the great leafy scales of the common sunflower. In other words, there is as



FIG. 176.

Bell-shaped and proterandrous flowers of common bell-wort.

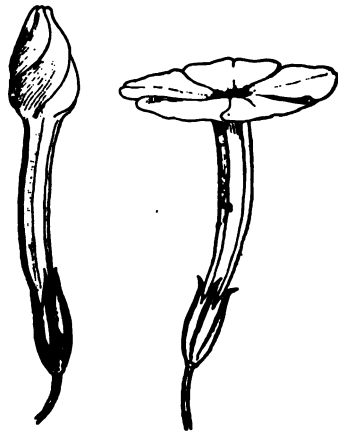


FIG. 177.

Salver-shaped corolla and convolute æstivation of phlox.

great variation in the involucre as in other members of plants.

SUGGESTIONS.—The pupil should designate the parts in the floret of the wild aster (Fig. 175); and the same exercise should be

extended to golden-rod, daisies, thistles, burdock, wormwood, bone-set, tansy, dahlia, zinnia, chrysanthemum, lettuce, salsify, chicory, ragweed, sunflowers, marigold, and other common composites.

XXXIV. FORMS OF THE PERIANTH

209. The petals of the hepatica (Fig. 131), mustard (Fig. 133), and various other flowers which we have seen, are all distinct or separate. The corolla, then, may be composed of several or many parts, and is then polypetalous.



FIG. 178.

Rotate corolla of eggplant. Stamens connivent (loosely joined together).



FIG. 179.

Inflated flowers of foxglove, showing peculiar valvate aestivation.

210. We have observed that the corolla of the squash (Figs. 161, 162) and of the florets of the composites is composed of a single piece, with the margin (or limb) variously toothed or parted. Such flowers are gamopetalous. In the same way, we may say that calices are polysepalous or gamosepalous.



FIG 180.

Labiate corolla
of catnip.

210a. Gamopetalous means "petals united," but the term should be understood to refer only to the fact that the corolla is in one piece, and not to express any opinion as to whether it is really composed of united parts. Monopetalous is often used in the same way as gamopetalous, but etymologically it means "one-petaled," and is, therefore, falling into disuse; al-

though one term is not much better than the other in a strict etymological sense. Words soon outgrow their etymologies or histories, and are defined by usage.



FIG. 181.

Irregular lipped flower of catalpa.

211. For purposes of description, the form of the corolla is designated by technical terms. It is likened to a bell, a trumpet, a wheel, or a sal-

ver; and many corollas are exceedingly irregular. The form of the corolla is most striking and definite in gamopetalous flowers. The important thing to remember, however, is not the name of the form, but the fact that there are multitudinous forms.

211a. Some of the characteristic forms of corollas are shown in the engravings. Fig. 176, bell-shaped, or campanulate; Fig. 177, salver-shaped (limb flaring at right angles to the tube); Fig. 178,

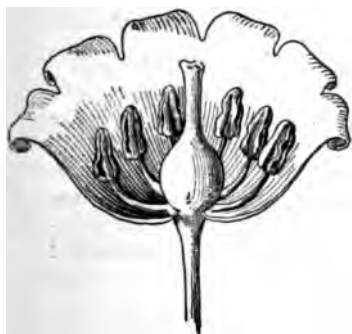


FIG. 182.

Lily-of-the-valley flower,
laid open.

rotate, or wheel-shaped, the limb being nearly circular and the perianth having practically no tube; Fig. 179, tubular-trumpet-shaped, or tubular-inflated (the morning glory is a typical example of a trumpet-shaped flower); Fig. 180, labiate, or two-lipped (characteristic of the mints); Fig. 181, lipped, or lobed, and therefore irregular flower. Flowers in which the parts or lobes of the calyx and corolla are all alike in shape and size, in the same series, are said to be regular (like Figs. 131, 133, 138, 139, 143, 144, 146, 148, 161, 162, 173B, 175, 176, 177, 178, etc.); others are irregular (as in Figs. 170, 179, 180, 181).

211b. When the parts in all the four series are of the same number, the flower is said to be isomalous. "Symmetrical" is generally regarded as synonymous with "isomalous," but symmetrical should be used to designate the fact that the parts of the four series are of the same number, or in multiples of the lowest number. That is, the petals may be five, but the stamens ten; in which case it is assumed that the stamens are in two rows of fives.

212. In the tulip (Fig. 138) and the lily (Fig. 148) there is no distinction between calyx and

corolla, except that three of the parts are exterior to the others. Such a corolla is called merely a

perianth, and the parts, when distinct, are all called sepals (173). It is found in all lilies, and, in fact, in most of the flowers which are built upon the plan of three (most of the parts in threes or multiples of three).

212a. The perianth may be gamosepalous, as in the lily-of-the-valley, Fig. 182. This perianth has six lobes, and there are six stamens. Compare the flowers of the common asparagus and the hyacinth.

213. The narcissus (Fig. 183) is peculiar. The sheath *b* cannot be a calyx, because the ovary is at *c*, and is borne upon a distinct stalk or peduncle. The part *b* must be a spathe, comparable with that in the calla (Fig. 168). It is seen that the flower is



FIG. 183.
The narcissus.

allied to the lilies because it is on the plan of three, and we should not, therefore, expect a distinct calyx and corolla. If one of the petal-like bodies is torn away, it is seen that the part *a* comes with it and is an integral part of it. This structure, *a*, is really an outgrowth of the perianth, and is known as a crown. The narcissus is, therefore, six-sepaled, as the lily is. The flower arises from a dry, papery spathe (compare the irises or blue flags, crocuses, gladiolus, and the like). It is seen, therefore, how we trace kinships in plants,—by means of similarities of origin and resemblances in structure rather than in looks.

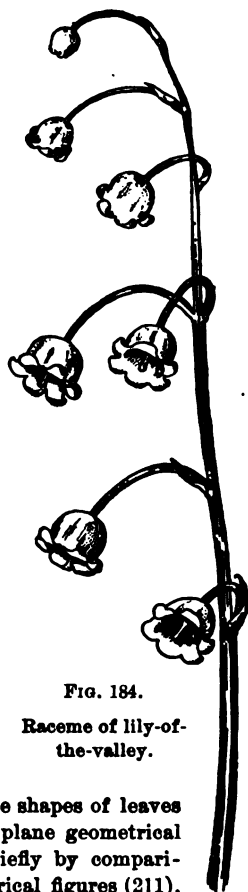


FIG. 184.

Raceme of lily-of-the-valley.

SUGGESTIONS.—The pupil has found that the shapes of leaves are designated by comparing them with some plane geometrical figure. Forms of perianths are designated chiefly by comparison with various receptacles or spherical geometrical figures (211), as cups, salvers, trumpets, bells, saucers, urns. Let the pupil select a flower which he may consider to be typical of any form, and then compare similar flowers with it in regard to form and size. He will soon find that probably no two flowers, as well as no two leaves, are exactly alike. It is excellent practice to make lists of the plants which one commonly meets, with reference to the make-up of the perianth. The pupil should observe whether

the perianth is polypetalous or gamopetalous, flower gamosepalous and polypetalous, flower gamopetalous and polysepalous, and the like.

XXXV. THE ARRANGEMENT OF THE FLOWERS

214. The hepatica flower (Figs. 131, 153) is solitary, and terminates the peduncle. The same is true of the tulip (Fig. 138). The flowers of the pepper (Figs. 113, 114), of the smilax (Fig. 102) and of the apricot (Fig. 47) are solitary and lateral. These are evidently the simplest ways in which flowers can be borne,—only one in a place. The two methods are distinct, however, for we have already discussed (Obs. iii., vi., x.) the significance of terminal and lateral flower-buds.



FIG. 185.

Raceme of currant.

214a. A peduncle which rises from the ground, and is simple or nearly so, and is usually devoid of foliage leaves and without nodes or joints, is called a scape. The hepatica, tulip and violet produce scapes.

215. Plants which bear lateral flowers may still grow from the terminal bud; and since new flowers

may arise as the plant grows, the oldest flowers may be constantly left farther and farther behind on the axis. That is, the flowers which first open are nearest the base of the plant. This type of branching is, as we have already seen (Obs. iii.), indeterminate in type. Plants which have terminal flowers must cease to grow from the ends of the axes, and lateral branches must continue the growth in length. Such type of branching is determinate, or diffuse.

216. If the lateral flowers of an indeterminate branch are close together, a flower-cluster results; and it opens from below (that is, from the base) upwards. Such a simple inflorescence is a raceme.

216a. The lily-of-the-valley (Fig. 184) is a typical example of a raceme. The leaves are reduced to mere bracts. The currant (Fig. 185) is also a good example.

217. If the pedicels in a raceme were obsolete, and if the flowers were close together, we should have a typical spike.

217a. The common plantain of door-yards (Fig. 186) bears its flowers in a spike. In such long spikes there is usually a gradual progression in anthesis (in the opening of the flowers) from below upwards, so that the spike is not in bloom simultaneously throughout its length. The lowest flowers often wither and die, as

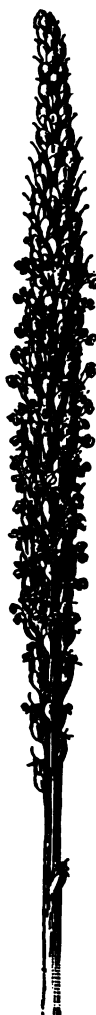


FIG. 186.
Spike of
plantain.

in the plantain, while the middle flowers are still in bloom. Special kinds of spikes, as we have found, are the spadix and the catkin. A much-condensed — much-shortened — spike is called a head.

218. If the lowest pedicels of the raceme were elongated (or the upper ones remained shortened)

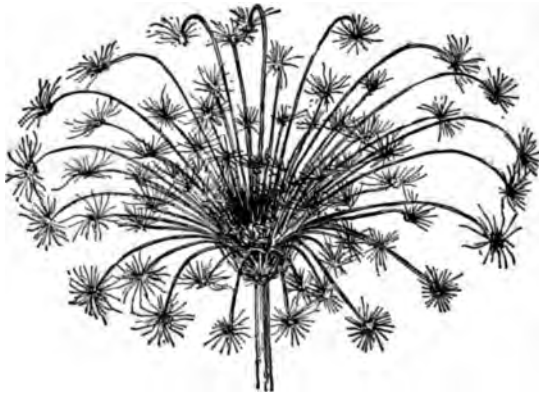


FIG. 187.

Remains of a last year's umbel of wild carrot.

so that the cluster were convex or nearly flat on top, we should have a corymb. That is, a corymb is an expanded cluster, in which the outermost flowers open first.

219. If the axis of the corymb were so very much shortened that all the pedicels seem to start from the same point, like the rays of an inverted umbrella, we should have an umbel.

219a. Umbels are characteristic of the plants of the parsley tribe, as parsnip, caraway, dill, celery, carrot and coriander. Often

the umbel is compound; that is, secondary umbels, or umbellets, are borne on the ends of the rays (as the pedicels of an umbel are often called). The bracts which subtend the pedicels in the raceme and corymb become verticillate under the umbel, or form an involucre; and the umbellets may be provided with involucrels. A last year's umbel of the carrot (Fig. 187) is seen to bear the remains of umbellets.

220. The inflorescence of the common arrow-leaf of the bogs is seen in Fig. 188. It is corymbose, for the lowest flowers open first. The axis elongates after flowering begins, so that the individual clusters are widely separated. The inflorescence appeals to one, therefore, as a series of whorled clusters. In other words, when the parts of an inflorescence are widely separated, particularly by subsequent growth of the axis, the inflorescence is described in terms of its parts, and not as a whole. Such a method of flowering may be called a progressive inflorescence.



FIG. 188.

Three-flowered whorls of
arrow-leaf.

220a. The arrow-leaf or *sagittaria* is interesting because the flowers (as also the parts of the perianth) are in threes, the significance of which may be suggested later. The lower flowers are commonly pistillate and the upper ones staminate.



FIG. 189.

Panicle of June-grass.

221. The inflorescence of June-grass (Fig. 189) is seen to be indeterminate, and yet it is not clearly racemose, spicate, corymbose, or umbellate. The fact is that the anthesis of the individual parts of such a flower-cluster may be mixed, although it is usually centripetal, or from below upward (outside to inward). This type of branching inflorescence is known as a panicle.

221a. Racemes are sometimes borne close together, in such a way as to suggest a panicle. The buckwheat (Fig. 190) is such a case.

XXXVI. THE ARRANGEMENT OF THE FLOWERS, CONCLUDED

222. In the basswood (Fig. 191) the central or terminal flower opens first. The branching is, therefore, determinate. This type of flower-cluster is called a cyme.

222a. The pupil should determine the morphology or significance of the singular leaf-like body *a*, Fig. 191, from which the peduncle springs; and he should discover if this member is characteristic of the lindens or basswoods.

223. The apple (Fig. 192) also bears its flowers in cymes, but the clusters are often only indefinitely determinate. That is, there is not always a definite progression in anthesis from inside outwards. Sometimes several of the flowers open



FIG. 190.

Racemose panicle of buckwheat.

topped clusters the outermost flowers must have the greatest advantage. This suppression or delay of the inside flowers often goes so far that the cluster is said to be corymbose-cymose.

nearly simultaneously, and sometimes the central flower is late; but the delay of the central flower is probably the result of the struggle for existence, for in dense and flat-



FIG. 191.

Cyme of basswood.

224. If the cymes were much branched, or compound, then the outermost cymules (or second-

ary cymes) might open first, and the cluster as a whole would have every appearance of being a corymb. Such compound corymbose cymes are common. The pupil may compare the hydrangea and the elder.

225. If one were to conceive of a cyme from which one of the halves were cut away, he would have a one-sided cluster which might strongly imitate a cluster of racemes. If the branches of this one-sided cyme were all removed except one, that one branch would imitate closely what is called a scorpioid or helicoid cyme; that is, a cluster which is one-sided and curled



FIG. 192.

Imperfect cyme of wild crab-apple.

or circinate at the end, with the oldest flowers at or near the base. This type of inflorescence is common in the borage tribes, like forget-me-not, heliotrope and comfrey.

225a. Other forms of cymose inflorescence are those in which the pedicels are so much shortened that the cluster is dense and

imitates a head. A true head, however, is corymbose (or opens from the outside, 185 a). Cymose heads are known as fascicles and glomerules.

225b. The teacher and pupil will now see that there are two ideas concerned in the study of the arrangement of flowers,—the general mode, method, or type of arrangement, and the particular kinds of clusters to which designative names have been given. To the mode of arrangement (whether cymose, corymbose, racemose, solitary, and the like) the name inflorescence is given. The word anthotaxy (literally "flower arrangement") has the same signification, and is now in frequent use, and etymologically it is preferable. Anthesis is practically equivalent to "flowering." It would be improper, therefore, to speak of a cyme as an inflorescence: it is a flower-cluster; but one could say that the inflorescence of the basswood is cymose or determinate.

226. If one were to examine the inflorescence of the Norway maple (Fig. 50), or of the horse-chestnut or lilac, he would observe that the anthesis is mixed. In the horse-chestnut and lilac, the general branching is of the indeterminate kind, as indicated by the pointed form of the cluster; but the side branches are more or less determinate. Heavy clusters like these are described under the general name of thyrses. They are really dense panicles, and it is impossible to draw any hard and fast line between the one and the other.

227. We have now learned the names which are currently given to the different forms of flower-clusters; but the most important lesson to be derived from the study is the fact that the exceptions may be the rule. That is, there are no forms so rigid that they may not be variously modified

or broken, and we must not infer that those forms to which we have given designative names are type-forms from which the others have been derived; but that they have been named simply because they are regular, and are, therefore, capable of definition. It is quite as probable that the mixed inflorescences are more nearly type-forms, in the sense of being original forms, than that the definite and regular ones are.

SUGGESTIONS.—The pupil should now examine any flower-cluster which he meets. Look especially at the heads of composites, the clusters of strawberries, grapes, blackberries, snowballs and elders (Fig. 193). Endeavor to find a spike which begins to flower at the top. Determine if the method of branching of the cluster is in any way related to the branching of the plant which bears it.

XXXVII. THE KINSHIPS OF THE FLOWER

228. We have already discovered (Obs. xxviii.) that it is often difficult to determine just where the leaves end and the flowers begin. That is, there may be a gradation from foliaceous leaves to bracts, to involucre or to calyx. The sepals and petals bear so much resemblance to leaves that they are popularly called the "leaves of the flower," and their arrangement, particularly in the bud, can often be expressed in definite phyllotaxy.



FIG. 193.

Compound corymbose cyme of elder.

Flowers occupy positions similar to branches: they spring from the axils of leaves (or bracts), and the method of branching of the flower-cluster suggests that the parts of the inflorescence occupy the position of normal branches. Moreover, the peduncles may bear bractlets, as branches bear leaves; and now and then a peduncle is jointed, or has nodes. Even well-developed buds may sometimes appear upon flower-stalks, as in the case of the pear in Fig. 194. These various facts suggest that peduncles (and pedicels) may be likened to branches, and that the parts of flowers are akin to leaves.



FIG. 194.

Bud upon the stem of a pear, suggesting that the pedicel is really a kind of branch.

228a. The bud upon the pear stem is really a monstrosity (108a). The science which treats of monstrosities is known as teratology. These monstrosities are interesting because they are unusual or abnormal, but chiefly because they sometimes throw much light upon the morphology of the parts. That is, parts which now and then behave similarly, or which give rise to similar structures, may be expected to have somewhat close homological relationships. The student of plant morphology should consult Masters' "Vegetable Teratology."

229. The common water lily is seen in Fig. 195. Those who are familiar with the flower know that there is a regular gradation from the green

sepals to the white petals; and even a casual observation shows that the stamens grade off from



FIG. 195.

Water lily flower, showing gradations of parts.

the petals in the same way. This can be well made out in the picture; and the gradation is

also shown (from 3 to 1) in Fig. 147. The water lily is not the only plant which shows similar gradations; from which we may conclude that leaves, sepals, petals and stamens appear to be derived from the same type of plant member, or are serially related to each other.

230. The canna flower should be studied in this connection (Fig. 196). The ovary is at *p*, the sepals at *s*, three pointed petals at *c c c*, and the style at *e*. An anther locule is plainly shown at *f*, and in the live plant this is very conspicuous. The organ which bears it, therefore, must be a stamen. But this stamen is a leaf-like body, and extends beyond the anther into a more or less curled, petal-like colored part. This extension of the stamen is thought by some botanists to be a transformed anther locule, and by others to be an outgrowth of the filament; but whatever its morphology,

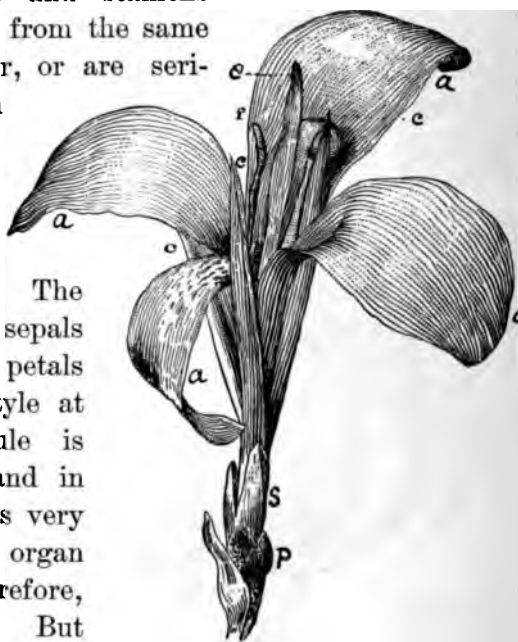


FIG. 196.

Canna flower.

it plainly shows the close kinship of the anther to the petal and the leaf. There are no other



FIG. 197.

Leaf-like carpels of the platanus-leaved *sterculia*.

stamens in the flower. From their positions, and from homology with related flowers, the showy parts of the flower, *a a a a*, are held to represent stamens.

230*a*. In common with all sterile or antherless stamens, and bodies which stand in the place of stamens, these petal-like bodies are called staminodia. The pupil will find two staminodia, in the shape of rudimentary bodies, in Fig. 151, standing just below the connectives.

231. The *sterculia*, or so-called Japanese varnish tree, which is now much cultivated in the South, has a most curious method of bearing its seeds, as shown in Fig. 197.

The carpels separate, even before maturity, into leaf-like bodies, upon which the seeds are borne.

(The carpels are usually five, but the number varies to four.) Although the foliaceous carpels of this *sterculia* are an uncommon type, they are not unique. Moreover, the pods of many plants split at maturity into more or less leaf-like portions. These facts suggest that even the pistil may be akin to a leaf.

232. The very best proof that the essential organs and the leaf are derived from similar sources is afforded by "double flowers." Fig. 198 is a double carnation flower. The extra petals (which make the flower full, or double) are plainly transformed stamens. They not only occupy the places of the ten stamens, but almost any bouquet of carnations will show various intermediate forms. In the picture there are anther locules transformed into petal-like bodies. This picture should be compared with the normal or single carnation in Fig. 152. The common double

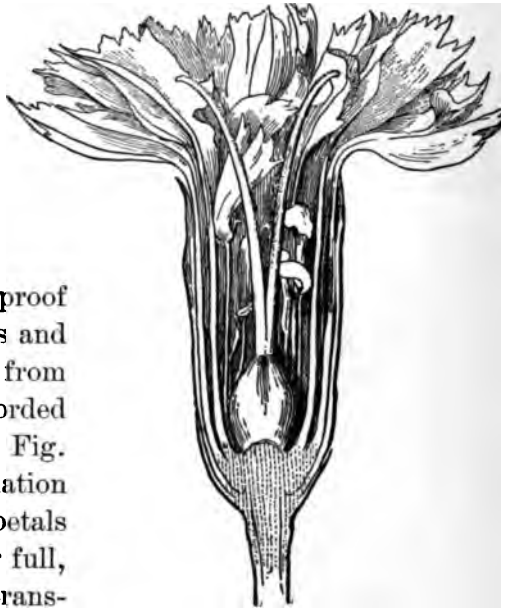


FIG. 198.

Double carnation
flower.

geraniums and tulips show most excellent gradations from stamens to petals, and often from pistils to petals. Fig. 199 shows the transformations in a double tulip. At *a* is a petal-like body with a portion of an anther upon its side, and at *c* the malformed

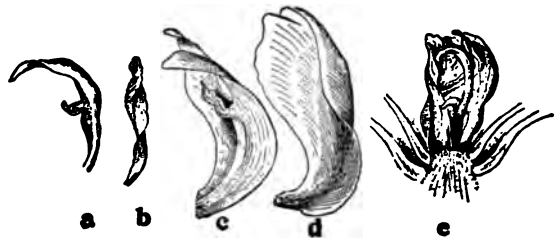


FIG. 199.

Transformations in a tulip flower.

anther is between two wings of the petal. At *d* is a body which stood in the place of a stamen, but upon which there is no rudiment of an anther. At *e* the single pistil of the tulip is seen to be broken up into a number of petal-like bodies. In roses and many other double flowers, not only the stamens but the pistils may directly change to petals, showing, therefore, that the kinship of the essential organs to the floral envelopes is actually very close and direct.

233. A blossom of the common double-flowering almond is shown in Fig. 200. Here the pistil and stamens are normal, showing that the extra

petals are adventitious growths (that is, appearing in unaccustomed places, neither from previously formed buds nor as transformations of other parts). This method of doubling is common; and even those plants in which the stamens and pistils are transformed, may develop many more petals than there are essential organs in the normal flower. This shows again, therefore, that the flower, like the leaf and the branch, is a plastic structure, capable of being greatly modified.

234. Plants which are kept in a very vigorous condition of growth generally bloom comparatively less than those which are making small growth. We have already seen (8) that checking growth may induce fruitfulness.

The gardener knows that if he would make his plants bloom profusely he must be careful not to grow them in too large pots, else the growth will be very great and at the expense of bloom. There is thus seen to be a most intimate relationship between vegetative growth and floral growth.

235. All these considerations lead us to believe that the parts of flowers and leaves are modified forms of one type or kind of plant structure.



FIG. 200.

Double-flowering almond.

235a. It is commonly taught that the parts of flowers are modified leaves. This idea seems to have originated with the poet Goethe ("Metamorphoses of Plants," 1790), who supposed that all the structures or members of plants may have been derived from the leaf. It has recently been suggested, however, that the evolution may have been in the reverse direction,—that leaves may have been derived from floral members. It is not necessary to accept either hypothesis, for both foliar leaves and floral members may have arisen independently from a common structure, as from stems; nor is it necessary to assume that all leaves or all flowers have arisen in the same sequence. The important lesson for the beginner is the fact that floral members and leaves are essentially alike in origin and that, upon occasion, one may pass into the other.

SUGGESTIONS.—In illustration of all these remarks the pupil should examine the double flowers of the gardens. Every one of these flowers has a story to tell of transformation or evolution; and every one is a witness that plants may be most profoundly modified by any treatment or condition which is strange to them. In particular, we may suggest a study of the common geraniums, carnations, roses, fuchsias, petunias, balsams, datura or brugmansia, violets, and tulips and hyacinths. The double aquilegias (or columbines) are very interesting; also the double larkspurs.

XXXVIII. PARTICULAR TYPES OF FLOWERS

236. The one thing which must have been most strongly impressed upon the pupil in these observations upon the flower is the fact of the great and wide variation in forms. We have already found many obscure or disguised parts. There are still other disguises, which will be sure to puzzle the pupil, to a very few of which we may give atten-

tion, by way of illustration. We shall be still further impressed with the fact that, while there are certain fundamental resemblances in flowers, there are endless differences in details.

237. An outline of the sweet pea flower is shown in Fig. 201. The calyx plainly has five parts, but the corolla evidently has but four. The prominent part is the standard or banner (also called the vexillum), shown at *s*. In front of it are two wings, *w w*. In the very front of the flower is a part which, because of its shape, is known as the keel, *k*. This pea-like type of corolla (which the

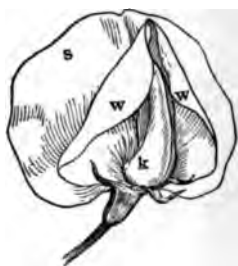


FIG. 201.

The sweet pea flower.

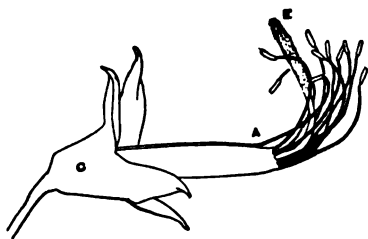


FIG. 202.

Essential organs of sweet pea.
Calyx at *c*, but corolla removed.

pupil will recall in the beans, clover, locusts, and the like) has been likened to a butterfly in shape; and such flowers are therefore said to be papilionaceous (Latin "papilio," a butterfly).

238. Searching, now, for the essential organs, we find a structure like Fig. 202. There are ten stamens, nine of them united by their filaments

into a tube which encloses the single pistil, one of them, *A*, remaining free along the upper side of the tube. The stamens in the pea-like flowers affect some such arrangement as this.

238*a*. In some plants the stamens are united in a single tube, and are then said to be monadelphous ("one brotherhood"); in other cases, as in the one before us, they are in two groups or companies, or are diadelphous.

239. If the parts of the calyx are five and the stamens ten, we are surprised that the petals should be only four, for we have found (172) that there is a strong tendency for the envelopes and the stamens to be represented by similar numbers or by multiples of the lowest number. We are to determine, then, if one of the parts of the corolla represents the union of two petals. In certain pea-like flowers the keel is represented by two petals, whence we conclude that in the sweet pea, garden pea, and other typical papilionaceous flowers, the keel represents two parts. The corolla of the pea, therefore, may be said to be built upon the plan of five.

240. Plants which bear papilionaceous corollas, ten monadelphous or diadelphous stamens and the particular kind of pod (called a legume) which is characteristic of the pea, are associated in a group or family known as the pulse family, or Leguminosæ. (Pulse is the generic name of seeds of peas, beans and the like.)

PARTICULAR TYPES OF FLOWERS, CONTINUED 209

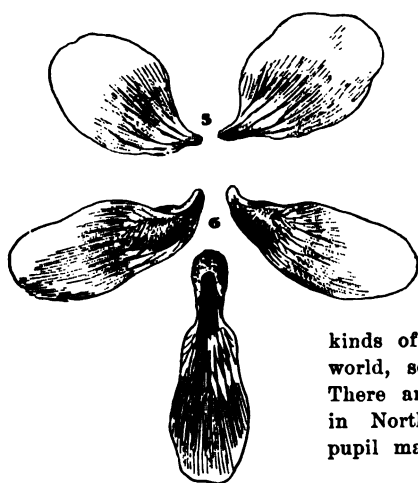
240a. A family is a more or less natural assemblage of plants which have a few bold or general resemblances. Nearly every family grades off into one or more other families, so that it is impossible to define it rigidly. The name of the family is a Latinized plural of some representative plant, or of some characteristic feature of the family as a whole. Families which are named from a representative plant are Rosaceæ, or rose family (from *Rosa*, the rose); Cucurbitaceæ, or gourd family (from *Cucurbita*, the gourd, pumpkin and squash); Solanaceæ, or night-shade family (from *Solanum*, the potato and its kin). Families named from some characteristic feature are Compositæ (compound or composite flowers), Cruciferae, or mustard family ("cross-bearing," alluding to the four petals, whose limbs are often arranged at right angles to each other); Graminæ, or grass family; Coniferæ, or cone-bearers. There are somewhat over 200 recognized families of flowering plants. The word order is often used in the same sense, but family is to be preferred.

SUGGESTIONS.—There are monadelphous and diadelphous stamens in other families than the Leguminosæ, but there are no other plants which have typically characteristic papilionaceous flowers. There are some Leguminosæ, however, which have regular flowers, but they are placed in the family because of their legumes and certain other features. The pupil should examine any of the mallow family for monadelphous stamens,—as cotton, abutilons, hollyhocks, hibiscuses, and mallows (the common round-leaved little weed known as "cheeses" is a mallow); also the passion flowers.

**XXXIX. PARTICULAR TYPES OF FLOWERS,
CONTINUED**

241. The flower of the common blue violet is displayed in Fig. 203. In general form it suggests a papilionaceous flower. It differs radically,

however, in having two petals on the upper side instead of one, and the lowest petal is morphologically only one (since the flower throughout is in fives). This lower petal is produced into a distinct sac or spur, which is characteristic of the violets. The stamens are five, with free filaments but connivent anthers, and the pod, which is 1-loculed, with three



7
FIG. 203.

Violet flower

placentæ, is much unlike that of the pea tribes. The violets, therefore, can claim no close kinship with the Leguminosæ.

241a. The violet is the type of a small family known as the Violaceæ, which comprises something like two hundred and fifty kinds of plants in various parts of the world, some of which are small trees. There are about sixty kinds of violets in North America. At this point the pupil may take up a study of the pansy.

242. The dutchman's pipe, or pipe-vine (a kind of aristolochia), is so-called from the curious pipe-like flowers (Figs. 204, 205). The plant grows wild from Pennsylvania southward

and westward, and is often cultivated upon porches and arbors for the shade of its great, dense



FIG. 204.

Flower of dutchman's pipe. Exterior view.



FIG. 205.

Dutchman's pipe. Longitudinal section.

leaves. The flower is most peculiar. The ovary is at *a*, and in this respect it differs radically from both the pea and the violet, in which the ovary is superior. The placentæ are axile. These are most important points in respect to the kinship of plants, and at once suggest a wide separation

of this dutchman's pipe from the Leguminosæ and from the Violaceæ.

243. It is next observed that the floral envelope is single; that is, there is only one series, and, following the botanist's rule, we call the flower apetalous. The calyx, however, is gamosepalous,—of one piece. This calyx has a curious enlargement at its base, *c*, and a constricted orifice (technically called a throat) where it joins the limb. The limb is 3-lobed. The essential organs (*q*, Fig. 205) consist of six short stamens, which are joined to a short style. The style bears a 3-lobed stigma. The plan of this flower is in threes, and the entire make-up is very unlike anything which we have seen.

243a. The aristolochias are either vines or upright plants, and they give the name (Aristolochiaceæ) to a small tribe known as the birthwort family, to which the wild ginger or *asarum* belongs. Several odd and showy tropical aristolochias are grown in fine conservatories.

244. The crape myrtle (Fig. 206) is one of the most common of cultivated bushes or small trees from Washington south. It is native of the East Indies, but is planted for the profusion of its rose-red or flesh-color, and rarely white, crispy flowers. The first thing to observe about this flower, as of any other flower, is the position of the ovary. This is superior. Its kinship is pre-

sumably, therefore (though not necessarily), nearer the peas and violets than the birthworts (247a).

245. The calyx is 6-lobed. Upon the calyx are borne the petals and the numerous stamens,



FIG. 206.

Flower of crape myrtle.

of which the six outermost are long and prominent. The style is single and slender, but the ovary is 3- to 6-loculed. The striking feature of this flower is the wide-spreading crimped petals, which are borne upon distinct stalks or claws; but the essential features of it are the characters associated with the relative numbers and positions of the parts.

246. We have now seen flowers in which the parts are arranged in threes, fours, fives and sixes. This numerical order is very important in determining the kinships of plants. It is most apparent in the floral envelopes and in the andrœcium, but it is very apt to appear in the pistil in the number of locules or placentæ, or in the styles or stigmas.

246a. To indicate the numerical plan, the number is prefixed to the Greek word "merous," denoting member: as 2-merous, 3-merous, 4-merous, 5-merous, 6-merous, and the like,—written in full respectively, dimerous, trimerous, tetramerous, pentamerous, hexamerous.

246b. The pupil will now see that (except in the 6-merous plan) the crape myrtle is really very suggestive of the plum flower (Fig. 144), for each is apparently perigynous, polypetalous and unipistillate.



FIG. 207.

Alleghany vine, or adlumia.

247. The bleeding-heart of the garden is familiar. It has a characteristic pattern of flower. The squirrel-corn and dutchman's breeches of the spring copses are close of kin. So is the Alleghany vine or smoke vine (or adlumia) of moist woods, flowers of which are shown in Fig. 207. The ovary is superior and has two placentæ; stigmas two. The sepals are two, minute and scale-like—well shown in the picture. The petals are four, and united into a

curious heart-shaped corolla. The stamens are six. This flower, therefore, is dimerous; but because of its hypogynous character and the presence of all four of the floral series (and the character of its fruit), it is evidently closer kin to the peas and violets than it is to the birthworts.



FIG. 208.

Flowers of the grape.

247a. We must not think of these resemblances in plants as necessarily expressing close genealogical relationships, but rather as similarities in structure or conformation which allow them to be classified. The adlumina and bleeding-heart would seem to be closely allied to the families which have gamopetalous corollas, but most of the closely associated plants are polypetalous, and it is held, therefore, to be a departure among polypetalous plants. The mere fact of polypetaly, gamopetaly or apetaly is held to be less significant in classification than formerly.

XL. PARTICULAR TYPES OF FLOWERS, CONTINUED

248. Grape flowers are shown in Fig. 208. An unopened flower is at 1. The balloon-shaped portion is the corolla. The calyx is merely a rim or disc at the base. The petals break apart from

below, cohering at the top, and are cast off in one piece by the expanding stamens, 2. The flower, therefore, is said to be calyptrate, or hooded. This is the "shedding of the caps" of which grape-growers speak. At blooming time, these flattened star-like caps may be seen upon the ground. The fully expanded flower is seen at 3; it is naked, and might be mistaken for a true achlamydeous flower.

249. In most of the flowers which we have studied, the stamens are alternate with the petals when they are of the same number; and this is the prevalent arrangement (an exception in Fig. 146). In the grape, however, the stamens are opposite the petals (2); and it is no doubt for this reason that they are able to raise the cap. Alternating with these stamens are five glands, or slight elevations, well shown in 2 and 3. These may be supposed, therefore, to represent stamens, since they occupy the position of stamens. This suggests that when stamens are opposite the petals or the lobes of the corolla, the pupil should look for other or rudimentary bodies which may be considered to represent missing stamens.

249a. A gland is a secreting body, as one which secretes nectar or honey, as these glands of the grape do; but the word is also applied to various small or supposedly rudimentary bodies which may not secrete.

250. One of the passion flowers is shown in Fig. 209. It is one of the oddest of flowers, and

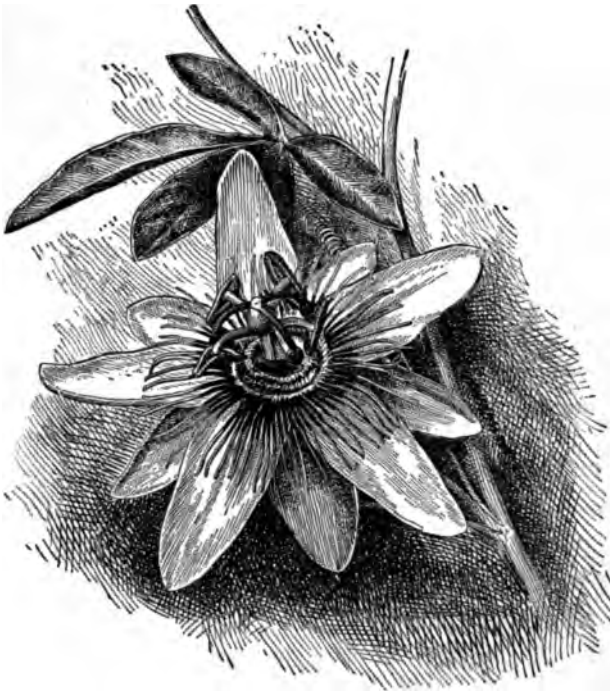


FIG. 209

A passion flower.

needs a special interpretation. The ovary (not shown in the picture) is superior. Below the flower are three bracts (not shown); then follows the calyx with five petal-like divisions; and alter-

nating with the divisions and borne upon the calyx, are five petals. The central part of the flower is occupied by five monadelphous stamens with



FIG. 210.

Flowering spurge.

versatile anthers, and out of the tube formed by the filaments project the three styles, with their capitate or ball-like stigmas. It now remains to interpret the hair-like fringe which stands above the petals. This arises from the petals, and, therefore, is of different origin from the stamens, and cannot be interpreted as stamens. We have found a comparable struc-

ture in the narcissus (Fig. 183). It is a crown or corona. The passion flower, therefore, is described as a perigynous, polypetalous, quadriserial flower, and presumably is not far removed, in classification, from the crape myrtle (247a).

251. A picture of the flowering spurge (*euphorbia*) is at Fig. 210. It appears to be a simple flower with five white petals, five or six stamens, and a curious 3-merous pistil; but this supposition is wholly wrong. The five petal-like bodies are expansions of an involucre; the apparent stamens are each a staminate flower arising from the axil of a bractlet and standing upon a jointed

pedicel, and the central object, 8, is a solitary 3-merous pistillate flower. The entire structure or supposed flower, therefore, is a monœcious reinforced head.

251a. This euphorbia is a common weed in many parts of the country. It is an herb, growing two or three feet high in dry soil. If this plant cannot be had, the pupil may find other spurges, for they are common; or he may ask a gardener for a plant of poinsettia or for one of the thorny euphorbias of greenhouses; or he may easily grow the variegated spurge, seeds of which are sold under the name of "snow-on-the-mountain." All the spurges have

milky juice. The pupil should make an earnest effort to obtain some euphorbiaceous flower for dissection. The flowers of the castor bean, although not in involucre heads, will be useful in this connection, for this plant is one of the Euphorbiaceæ.

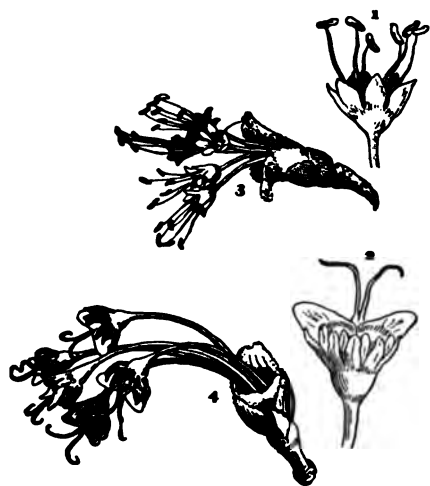


FIG. 211.

Flowers of red maple.

251b. The pupil may be asked to explain the flowers of the red or swamp maple in Fig. 211. The picture may suggest an euphorbiaceous type of flower, but the pupil must not be misled by appearances. These red flowers of the maple are among the very earliest flowers of spring, appearing while the branches are still bare of leaves.

252. One of the most reduced of flowers, in point of size, is that of the duckmeats, or lemnas. These are minute plants (Fig. 212), comprising

only a floating leaf (or frond) and one or more hanging roots. They are common upon stagnant pools, often covering the water with a blanket of green. Three plants of one of the common kinds are

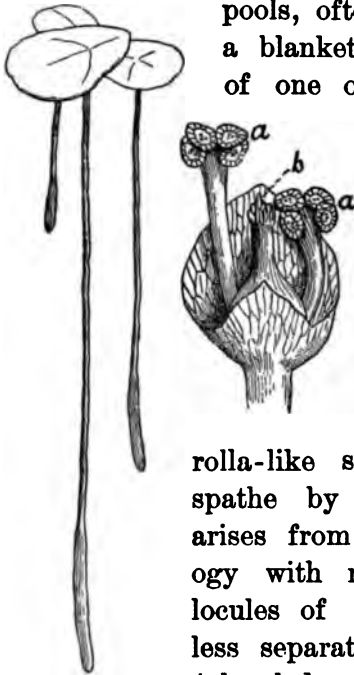


FIG. 212.

Duckmeat.

shown, about six times enlarged, in the picture. The flowers (shown at the right) spring from the margin of the frond, and consist of two flowers of a single stamen each and a single pistillate flower, the three borne in a co-

rolla-like spathe (determined to be a spathe by the manner in which it arises from the frond and by homology with related plants). The two locules of the anthers are more or less separated, as if the anther were 4-loculed. The presence of the spathe at once removes this plant from those groups which we have chiefly studied,

and associates it rather with such types as the calla and narcissus.

253. In all these various types of flowers we have been able to go beyond the mere external resemblances and to discover some relatively funda-

mental points of comparison ; and by means of these points we are able to construct classifications. Some of the points of most importance in comparative studies of flowers are: the numerical plan; the relation of the parts with reference to the ovary; the coalescence of parts or series; the reinforcement of the flower.

SUGGESTIONS.—With the suggestion of the last paragraph in mind, the pupil should compare the various flowers which he commonly meets. If a dozen or more flowers of different kinds can be had at once, it is excellent practice to construct a method of arranging or classifying them into groups or series. If the teacher were to consult a gardener sometime in advance,

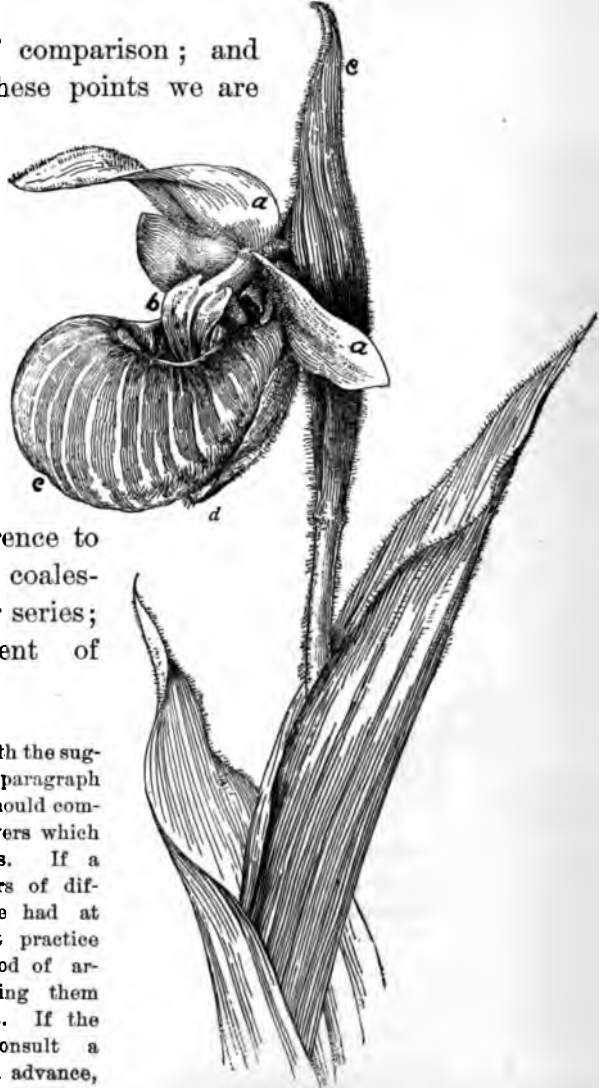


FIG. 213.

Wild lady's-slipper.

a collection of flowers for this study could be easily secured in winter time. Even without previous notice, he might be able to supply carnations, violets, fuchsias, heliotropes, geraniums, begonias, alyssum, hyacinths, roses, freesias, oxalises, bouvardias, lilies-of-the-valley, mignonette, pansies, chrysanthemums, cinerarias.

XLI. PARTICULAR TYPES OF FLOWERS, CONTINUED. (THE ORCHIDS)

254. A lady's-slipper, or cypripedium, is shown in Fig. 213. The flower is exceedingly irregular.



FIG. 214.

Column of a greenhouse
cypripedium.

There are four obvious petal-like parts, *a a b d*, and a sac (or "slipper") *c*, which is no doubt a part of the perianth. This makes only five parts. A study of homologies in other cypripediums, however, shows that the lower member, *d*, represents two united parts, and we must believe that the flower is trimerous. The three parts standing for the calyx are the outermost ones, represented by the united parts, *d*, and the upper one at *a*. The parts representing petals, then, are the side pieces *a* and *b*, and the sac *c*.

255. The essential organs of a cultivated cypripedium are shown in Fig. 214. Two anthers are at *a a*. A petaloid body representing a third stamen stands above them at *b*. This is known to represent a stamen, because in most orchids this uppermost body is a fertile anther and the lateral bodies are rudimentary. The lip-like body, *c*, is the stigma. In Fig. 213 this staminodium (230*a*) is represented by the ladle-like body projecting into the sac at *b*.

256. The most important thing to note about these essential organs is the fact that they are united into one body. That is, the stamens and pistil are grown together, or are said to be gynandrous. The body formed by this union is technically known as a column; and it is the chief distinguishing mark of orchids.

256*a*. Orchids are plants with irregular trimerous flowers, with a one-loculed inferior ovary and three parietal placentæ, and gynandrous stamens, of which one or more is sterile. One of the petals, or inner divisions of the perianth, is often sac-form. There are about five thousand kinds of orchids known, most of which are herbs. They chiefly inhabit the tropics, but there are many humble and local species in the northern United States and Canada, growing in woods and bogs. In the tropics many of them are epiphytes (growing upon trees), and in the North some of the species are parasitic upon the roots of trees, and are destitute of foliaceous leaves. Numbers of tropical species are cultivated in glass houses. Among the better known plants which are members of the Orchidaceæ are the lady's-slippers or cypripediums, rattlesnake plantain, putty-root and vanilla.

257. One of the pogonias (a rose-colored orchid which inhabits bogs in the northern states and



FIG. 215.

Flower of pogonia.

Canada) is shown in Fig. 215. The ribbed ovary is seen below the flower. The lip, which is a sac in the lady's-slipper, is an enlarged fringed member, but the other parts of the perianth are much alike. The column is a club-shaped body lying just above the lip, and the end of it is covered



FIG. 216.

Bullrush.

by the single lid-like anther. This flower is very unlike the lady's-slipper in general appearance, but the fundamental characters of the flower clearly show the kinship of the two.

258. The orchids are exceedingly various among themselves; that is, they run into many forms. This means that they are highly specialized, or adapted to special or particular conditions.

258a. Specialization is a term employed to denote modification by means of evolution, which adapts a plant (or animal), or any part of it, to particular environments or functions.

258b. Generalization denotes the absence of such special adaptations. The word is used in connection with organisms (that is, plants or animals), or their parts, which



FIG. 217.

Spike and flower of *rye*.

have attributes that fit them for a wide or common range of conditions. Generalized organisms are usually relatively simple, or undifferentiated in structure the one from the other; they are conceived to be fundamental or stem types, from which specialized ascendants may arise in the long courses of time. The orchids are highly specialized plants.

258c. The environment is the sum of all the conditions or circumstances in which a plant or an animal lives. Literally, it means the surroundings. The climate, soil, elevation and the like comprise the environment.

SUGGESTIONS.—Inasmuch as orchids are local or rare in most parts of the country, the pupil may be obliged to resort to the florist for specimens, although cypripediums are frequent in many places. The larger greenhouse establishments usually grow such orchids as East Indian cypripediums, lyeaste, phalænopsis, cattleya and calanthe.

XLII. PARTICULAR TYPES OF FLOWERS, CONTINUED. (GRASS-LIKE PLANTS)

259. Portions of the common bullrush, which grows in clumps in low grounds, are shown in Fig. 216. The paniced inflorescence is at *a*, and an enlarged flower at *b*. The perianth is composed of six pointed greenish sepals. (The pupil should determine the significance of the scales which are shown beneath the perianth in the picture.) The stamens are three, and stand against the outer sepals. The pistil is 3-loculed, with three feather-like styles. The flower is, therefore, regular and simple in structure, and this suggests that it is not highly specialized.

260. Rye is drawn in Fig. 217. The spike (called a "head" by farmers) is at the left, and a flower is enlarged at the right. The pistil, with two feathery styles, is seen in the center at *a*, and there are three stamens with versatile anthers, *b b b*. There are two parts, *c c*, which might be taken for petals. The flower is, therefore, wholly unlike the rush in its plan, and suggests that the two plants are not close of kin.

260*a*. Similar structure can be made out for the flower of June grass in Fig. 218, which is a flower taken from the panicle in Fig. 189.

261. If the flowers of grasses were examined with care, however, two or three minute scales would be found at the base of the ovary; these (known as lodicules) are held to represent the perianth. The two petal-like bodies, then, must be reinforcements of the flower, and they are now considered to be specialized bracts (or glumes). The outer bract (seen on the right in the picture of rye and on the left in Fig. 218) is called the flowering-glume, and the inner and smaller one the palea. They were formerly called the outer and inner—or lower and upper—paleas. These are characteristic features of the



FIG. 218.

Reinforced flower of June-grass.

grass flower, and the rush, which, to casual observers is a grass, really belongs to another family.

262. In Obs. xxx. we became acquainted with the pistillate spike of Indian corn (Fig. 167), and the pupil was asked to find the staminate flowers. Some of these staminate flowers

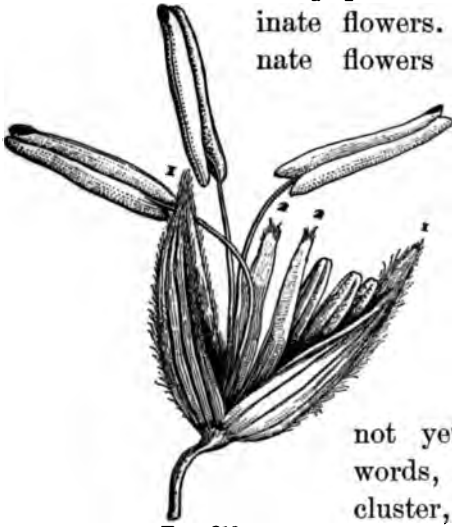


Fig. 219.

Staminate spikelet of maize.

are shown enlarged in Fig. 219. It will be seen that there are two flowers in the little cluster, each comprising three stamens, and the flowering glumes are at 1, 1, and the palets at 2, 2. The flower at the right is

not yet in bloom. In other words, Fig. 219 shows a flower-cluster, or a part of one.

This is called a spikelet, a term applied, in the grasses, to the closely associated flowers upon the ultimate branches of the cluster. The pupil will at once catch the resemblance of these flowers to those of the rye and June-grass, and will be prepared to be told that Indian corn belongs to the grass family, although it looks much less like grass than the rush does.

262a. The pupil will now be interested in an attempt to make out the bracts or glumes in the pistillate inflorescence of corn (the ear), and he will find that the kernel or grain very soon outgrows the bracts. Do these bracts remain upon the cob? It would interest the pupil if he were to grow a few hills of the "husk corn" (seed of which is often sold by seedsmen), in which each kernel is still enclosed in the glumes at maturity.

263. If, now, we return to the spike of rye (Fig. 217), and examine the lowest spikelet on the front, we observe that the lowest glumes are not so long-awned as the flowering-glume is in the single flower at the right. They are empty glumes; that is, there are no flowers above them. This shows that each spikelet is really a shortened branch, and the lowest bracts usually remain empty, as we have found (42) the lowest leaves upon a shoot to remain devoid of good axillary buds. The spikelet of rye is said to be 2- to 3-flowered, but only one or two of the flowers develop. A knowledge of a common branch, therefore, aids us to interpret even such complex structures as the inflorescence and flower of a grass.



FIG. 220.

Compound spike of *Carex*.

263a. The grass family comprises not only the plants which we commonly know as grasses, but also all the cereal grains, as wheat, maize, rice, barley, rye, oats and also sorghum and sugar cane.

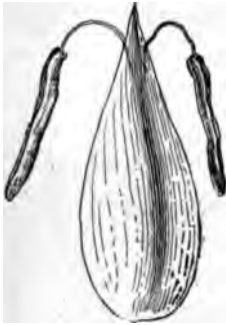


FIG. 221.

Staminate flower
of carex.

The bamboos are grasses. The group is probably most abundant in actual number of plants of any family of flowering plants, but the number of distinct kinds is less than in several other families, numbering about two thousand five hundred. There are two recent monographs upon grasses which the pupil may easily procure: Hackel's "True Grasses" (translated by Lamson-Scribner and Southworth), and Beal's "Grasses of North America." The latter is in two volumes, the first comprising a general discussion and an account of the agricultural status of the grass tribes, the second containing a description of the North American grasses. Descriptions of the different kinds of grasses, with special reference to their agricultural uses, may also be found in various publications issued by the United States Department of Agriculture.

SUGGESTIONS.—The grasses are too critical (the floral parts too minute, too similar and too much disguised) to be profitable subjects of study for the beginner, but the pupil should observe the manner of inflorescence of the different kinds, and he should especially be able to determine the blooming time of the grains and meadow grasses.

XLIII. PARTICULAR TYPES OF FLOWERS, CONCLUDED. (SEDGES)

264. We have already been introduced to the sedges (Obs. xxx., Figs. 165, 166). The same sedge which is seen in flower in Fig. 166 is seen fully ripe

in Fig. 220. The entire flower-cluster is a compound spike. Two of the spikelets are subtended by bracts, *b b*. If the staminate portion of the spikelets were examined, two bare stamens would be seen arising from behind a scale (Fig. 221). The pistillate flower (Fig. 222) has two styles which

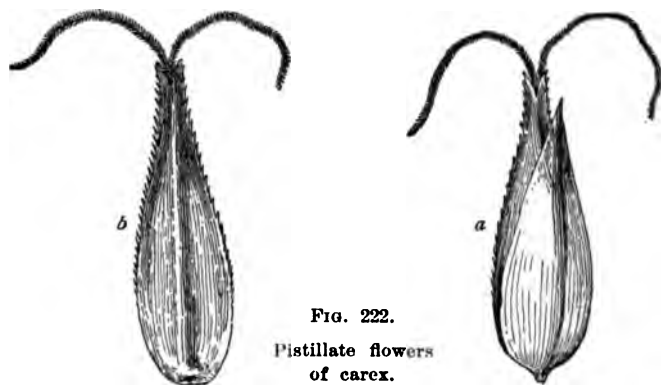


FIG. 222.
Pistillate flowers
of *Carex*.

project from a flask-like body, and this body, like the staminate flower, is borne in the axil of a bract. Where is the perianth?

265. A sedge of the type shown in Fig. 165 would ripen into a form something like that in Fig. 223. (The two are not the same kind, however.) Leaf-like bracts subtend each spike. A pistillate flower of Fig. 223 is enlarged in Fig. 224. It is in the axil of a scale. The side of the flask-like body is torn away, and the 3-an-

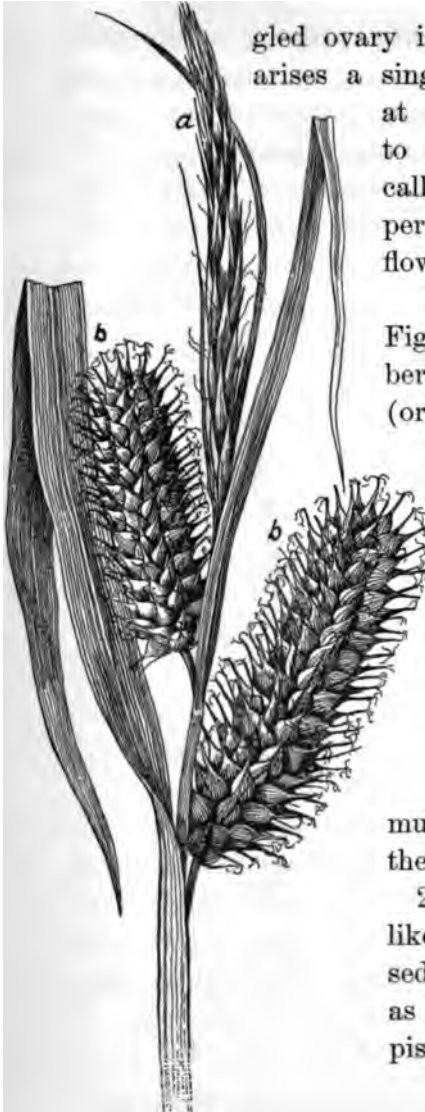


FIG. 223

Spikes of a carex.

gled ovary is seen within, from which arises a single style which is 3-lobed at its summit. There seems to be reason, therefore, for calling this flask-like body a perianth; but the staminate flower is naked.

266. The flower at *a* in Fig. 225 contains a new member in the form of a branch (or racheola) which arises beneath the ovary. This racheola not infrequently projects beyond the flower and bears other flowers (*b*); and in some kinds of *Carex* a similar structure is the rule. If this branch is inside the flask-like body, then that body cannot be a perianth, but must be a reinforcement of the flower.

267. This enclosing or flask-like body in the *Carex* or sedges is technically known as a perigynium ("around the pistil"), and it probably rep-

resents a bractlet which has rolled itself into a flask (or possibly two conjoined bracts). The scale which subtends the perigynium, therefore, must be a bract at the base of a very short branch, and this branch bears the perigynium and the flower.

The flowers of *Carex* are interpreted to be achlamydeous; and if the ultimate branchlet in the inflorescence of a grass is called a spikelet, a similar term should be applied to the perigynium and its flower if we follow strict homologies.



FIG. 224.
Pistillate flower
of a *Carex*.



FIG. 225.
Rachecola of *Carex*.

268. We are again impressed with the fact that the morphology of a flower or a part cannot be inferred from mere external conformation, for appearances are apt to be deceitful; and we see how important it is to give careful attention to every secondary and incidental part or structure.

SUGGESTIONS.—The sedges are even more critical than the grasses, but they are so abundant that the pupil should take pains to observe them. He should at least be able to distinguish them from grasses. They may be readily distinguished by the phyllotaxy (68). The stems or culms are generally 3-angled, particularly in the

larger kinds, and the foliage is usually harsh or rough. There are many types of sedge-like plants, but the term sedge is commonly restricted to the plants of the group or genus *Carex*, which is considered here. Carices are very common and abundant. Observe the variation in the number of styles in the various kinds of *Carex*, and determine if the number of stamens varies at the same time.

XLIV. CROSS-FERTILIZATION

269. We have found (140) that the purpose of the flower is to produce seeds; these seeds cannot be formed without the aid of pollen; comparatively few flowers are perfect and also synanthous (or simultaneous) in the maturation of pistils and stamens, and very many flowers are imperfect. It would seem to follow, therefore, that cross-fertilization is the rule, and we infer that it must result in some decided benefit.

269a. Fertilization or fecundation is the action of the pollen upon the body which develops into the seed.

269b. Close-fertilization or self-fertilization is the action of the pollen upon the pistil of the same flower.

269c. Cross-fertilization is the action of pollen upon the pistils of another flower. The term is often restricted to fertilization between flowers upon different plants, although this is unwarranted.

269d. Pollination is the act or fact of conveying the pollen, whether by bees, wind, man, or other means.

270. The simplest means by which cross-fertilization is enforced is by dichogamy, or the different

times of maturing of the organs of the same flower (150a). Certain simple movements or habits of the pistils or stamens are often associated with dichogamy. Fig. 226 is a flower of one of the wild phloxes. The stigmas are seen to be three, but these are closed until the stigmatic surfaces are receptive, which commonly occurs after the pollen is discharged. A similar behavior may be detected in the blue-bells in Fig. 176. In the middle flower the style is merely club-shaped; in the lowest flower, the style has opened to three branches, but the anthers are shrivelled. Inasmuch as the period of blooming of any plant usually extends over several days at least, the dichogamous flower is likely to receive pollen from various flowers which are borne either upon the same or another plant.

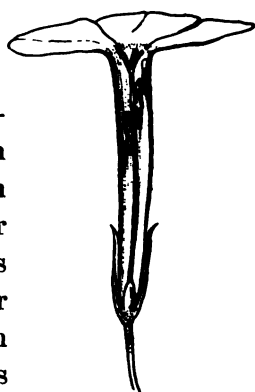


FIG. 226.

Dichogamous flower of
phlox.

270a. Pistils of dichogamous flowers may accidentally receive pollen from the same flower; but Darwin and others have found that pollen is often impotent, or sterile, upon the associated stigmas. That is, if pollen from the same and from another flower were to fall upon a stigma, the foreign pollen is the more likely to be fecund. Foreign pollen is commonly prepotent. If, however, no pollen is received from another flower, the stigma may accept the pollen from the associated anthers.

271. It is evident that if self-fertilization is so often excluded, the plant must frequently depend upon extraneous agents for the transfer of pollen and the perpetuation of its kind.

272. If the pupil were to shake the staminate catkins of the hazel, birch or walnut when they are mature, he would be surprised at the showers of pollen which are discharged; and if he should watch the destination of this pollen he would probably see that some of it chances to drop upon the pistillate flowers. He may make similar observations with Indian corn and staminate pine cones. A common agent in distributing pollen is the wind. Plants which bear protruding feathery stigmas and protruding stamens (as the grasses) are generally wind-pollinated. So are many or most diœcious or monœcious plants.

273. We have already referred to the fact (150) that the showy petals sometimes attract insects. The insects are also attracted by odors, as one may infer by watching the visits of moths to the pe-tunias at nightfall, at which time the flowers give forth their odor. We would infer, therefore, that those flowers which have neither showy colors nor odors must be pollinated by the wind; and this is true, as a general statement.

273a. Plants habitually pollinated by the wind are said to be anemophilous ("wind-loving"), and those pollinated by insects entomophilous ("insect-loving").

273b. Since the publication of Darwin's remarkable investigations upon the inter-relations of flowers and insects, it has been commonly supposed that the showy colors of flowers have been developed, or have originated, as a means of attracting insects, but this explanation of the origin of colored parts is open to doubt. But whatever the evolution of the corolla may have been, it is known that color and perfume often attract insects.

274. It is evident that the insect would not visit the flower for the flower's sake, but for its own sake. There must be something in the flower which it wants, for color and odor are only attractions, not substantial rewards. The things which the insect wants are nectar (or honey) and pollen, chiefly the former.



FIG. 227.

Flower of columbine.

275. A flower of the columbine (often erroneously called honeysuckle) is shown in Fig. 227. The petals are produced into long spurs. If one of these spurs were opened when the flower is in full bloom, the bottom of it would be found to contain a glistening secretion. This is the nectar; and the spurs are, therefore, nectaries.

275a. Humming-birds are fond of sipping the nectar from the columbine, for which their long bills are eminently fitted. Bees

also crowd into the tubes. Bumble-bees often bite open the nectaries and steal the honey from the outside; this kind of theft is not infrequent in other flowers.



FIG. 228.

Flowers of common
buttercup.

276. The pupil should now examine any of the buttercups, or crowfoots. The common one in the East is shown in Fig. 228.

If the petals are pulled away, each one is seen to bear a minute gland or lip (*b*) at its base. This is the nectary. The disk-like base of the grape flower (Fig. 208) is also a nectary. As a rule, entomophilous flowers bear nectaries, and they are usually located in the very base or bottom of the flower.

SUGGESTIONS.—The pupil should now look for the nectaries in all flowers which he suspects to be insect-pollinated. The presence of spurs and sacs, and also of glands, is presumptive evidence of nectaries. The presence of insects about flowers always raises the presumption that those flowers are entomophilous; the pupil should, therefore, determine what visitors the common flowers may have.

XLV. CROSS-FERTILIZATION, CONCLUDED

277. If the flower is to be pollinated by the visit of insects, there must be some special contrivances or adaptations in the flower by which that end is accomplished. Fig. 229 shows two flowers,

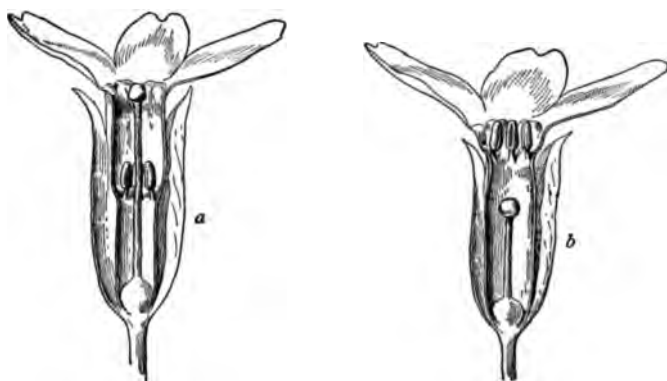


FIG. 229.

Dimorphic flowers.

in longitudinal section, of the polyanthus, or primrose, of old gardens. The relative positions and lengths of the essential organs are unlike in the two. When an insect comes to *a*, it leaves upon the protruding stigma some of the pollen which was caught upon its body when it backed out of the flower *b*; but when in *a*, it got its head dusted

with pollen from the short anthers. If, now, it goes to *b*, its head strikes the stigma of the short style and pollen is left there. In all this operation, the insect is no doubt wholly unconscious of its work in carrying the pollen; it is only intent upon the honey in the bottom of the flower-cup. No doubt the pollen from the different kinds of flowers becomes more or less mixed upon some of the stigmas, but the foreign pollen only, as we have seen (270*a*), is likely to be effective.

277*a*. This difference in relative lengths of stamens and pistils is characteristic of many kinds of plants. Flowers like the polyanthus are said to be dimorphic ("two forms"). Other flowers have, in addition, an intermediate length of organs, and are said to be trimorphic. Dimorphic and trimorphic flowers are also said to be short-styled, long-styled and mid-styled. Such flowers, as a class, are said to be heterostyled; but Gray has proposed that they be called heterogonous, since the polymorphism applies to the stamens as well as the pistils. The pupil may examine such plants as mayflower (*epigæa*), pickerel-weed or *pontederia*, oxalis, partridge berry or *mitchella*, large-flowered flax or *linum* of the gardens, buckwheat, and some of the loose-strifes or *lythrums*. The whole subject is presented in Darwin's book, "Different Forms of Flowers on Plants of the Same Species."

278. We have already made out the structure of the sweet pea (Obs. xxxviii., Figs. 201, 202). We shall now watch how the bees visit the flower (Fig. 230). The insect is after the nectar at the base of the flower, and in order to secure it, the bee alights upon the keel and forces its way in



FIG. 230.

Pollination of the sweet pea.

between the wings. In crowding itself in, the bee pushes down upon the keel, and its body is struck by the shaft of pistil and stamens (Fig. 202). Pollen is left upon its abdomen, and the next flower visited may receive some of it.

278a. This is only one example of the almost innumerable ways in which flowers are pollinated by insects. Some of the special contrivances for effecting pollination are remarkably beautiful and exact. We have found that the orchids are highly specialized. Much of this specialization is a direct adaptation to cross-pollination by insects; and the pupil who desires to pursue the subject of cross-pollination should begin with Darwin's epoch-making work, "The Various Contrivances by which Orchids are Fertilized by Insects." He should also have Mueller's "Cross-fertilization of Flowers."

278b. A special literature has sprung up respecting the cross-fertilization of flowers. The subject is a favorite, because it often shows such marvellous adaptations to particular ends. There is great danger, however, that study of the subject by beginners will lead the pupil to feel that perfect and complete adaptation is a universal fact in nature, and will cause him to overlook the non-adaptations and the misfits, of which there are many. It is usually better for the beginner to obtain a somewhat general view of plants before going far into such special subjects; but the above observations suggest to him a rich field which awaits still further exploration.

278c. We are apt to assume that all structures and attributes of plants are for some distinct purpose or use, and we then set out to discover what those uses are. The inevitable result is that we find adaptations when there may be none. Every feature of a plant needs to be investigated for itself, in the light of its history or evolution. Some features may be found to be in process of adaptation, others in process of obliteration, and others are at the present time perfected; and it is likely that some others may be merely concomitants or correlatives of other characters, having been carried along with them and having no special significance.

279. A flower of one of the common milkweeds (*asclepias*) is shown in Fig. 231. An insect has alighted upon it. If this insect were examined after his visit he would probably be found to be carrying saddlebags (like *b*) upon his legs or tongue. The bags constitute the pollen, and each bag comprises the entire content of an anther locule. The handle or caudicle of these bags is attached in the chink or slit of a gland on the side of the stigma, and the insect, by catching its legs in this chink, drags out the bags and carries them, with the gland, to other flowers.



FIG. 231.

Pollination of milkweed.

279a. Such masses of pollen (which occupy the entire locule) are known as pollinia. Pollinia are characteristic of orchids and milkweeds, highly specialized plants of widely different families.

280. The dalibarda is a low dewberry-like plant (but resembling a violet) growing in woods in the northernmost states. It is shown in Fig. 232. A normal showy flower is at *a*. At *b* and *c*, however, there are clusters of seeds upon shorter

scapes, and if the plant had been examined two or three weeks earlier the flowers from which these seeds came would have been

seen to be apetalous and closed up tight in the calyx. They must, therefore, be self-fertilized. That is, some kinds of plants bear two kinds of flowers,—the normal, showy kind, fitted to attract insects, and the closed, inconspicuous kind, which are self-fertile.



FIG. 232.

Normal and cleistogamous flowers of dalibarda.

280a. These reduced and simplified flowers are said to be cleistogamous. The pupil will find similar ones in the common blue violet after the showy flowers have passed, in the fringed polygala, and in a common bean-like vine of woods, known as amphicarpæa.

281. The most conspicuous thing about these cleistogamous flowers is their simplicity,—the short peduncles or scapes, the absence of petals, the dwarfed and closed calyx, and the small amount.

of pollen. That is, there is most rigid economy in their make-up. It is an expensive business to advertise for insects: there must be a high development of color or odor (sometimes of both), large quantities of pollen, long peduncles, and the like. It is also wasteful of pollen to trust to the wind, as one may prove by shaking the staminate cones of pines or the catkins of the birches or walnuts and observing the showers of pollen which are discharged. All these expenditures tax the energy of the plant. The cleistogamous flowers are very fruitful. It is now generally held that they have been developed as a matter of economy, while the seeds of the showy cross-fertilized flowers impart sufficient vigor to the race, from time to time, to prevent it from running out. This explanation seems to account for the facts, and it is probably correct; but a hypothesis which merely accounts for the facts is not necessarily true. There may be other reasons why cleistogamous flowers have been developed. At all events, we must be careful not to explain everything upon the theory of adaptation.

SUGGESTIONS.—There is scarcely a flower which will not yield some unexpected interest if one watches it when insects are working upon it. Flowers of very irregular and striking shape, and with oddly constructed stamens and pistils, are usually specialized apparently for insuring cross-pollination by insects. Some aquatic plants cast their pollen upon the water, and it is thus carried to the pistils of other flowers. Birds and snails sometimes aid in transferring pollen.

XLVI. THE CROSSING OF PLANTS

282. If the means for insuring cross-fertilization are so general, it must follow that the crossing of plants serves the plant some useful end. It is known, as the result of much experiment, that crossing results in strengthening or invigorating the offspring which grow from the seeds of the cross-fertilized flowers.

282a. The best results are usually obtained when the cross is made between two distinct plants of the same kind,—not, on the one hand, when made between flowers upon the same plant, nor, upon the other, when made between wholly different kinds of plants. The fullest information upon this subject will be found in Darwin's "Effects of Cross- and Self-Fertilization in the Vegetable Kingdom."

283. If marked benefits follow normal cross-fertilization in wild plants, similar results should follow in cultivated plants; and there would seem, therefore, to be reason to perform the pollination by artificial means.

283a. As a matter of fact, crossing is rarely done by man for the purpose of improving the variety or kind, but rather—by crossing plants of different kinds—to produce new varieties or kinds. To this latter subject we shall revert at another time (534).

284. Plants naturally cross under cultivation as well as when growing in the wild, however, so that

nothing is lost in this regard by transferring them to the farm or garden; but in special cases it may be desired to perform the operation of pollination by hand, and instructions may therefore be useful. In order to insure the most definite results, every effort should be made to rightly apply the pollen which it is desired shall be used, and to rigidly exclude all other pollen.

285. The first requisite is to remove the anthers from the flower which it is proposed to cross, and they must be removed before the pollen has been shed. The flower bud is therefore opened and the anthers taken out. It is frequently most expeditious to cut off the floral envelopes with small, sharp-pointed scissors, then cut out or pull out the anthers,



FIG. 233.

Emasculation of maurandia bud.

leaving only the pistil untouched. Some operators prefer to simply open the corolla at the end and pull out the anthers with a hook or tweezers; and this method is often the best one. The method is not important, so long as the pollen is all removed and the pistil is not injured. The operation of removing the stamens or anthers is known as emasculation.

285a. In Fig. 233 the bud at the right has been emasculated. The other shows the size of the bud at the time of the operation. It is best to delay the operation as long as possible and yet not allow the bud to open (and thereby expose the flower to foreign pollen) nor the anthers to discharge the pollen.



FIG. 234.

Flower covered with a paper bag.

286. The emasculated flower must be covered with a bag to prevent the access of pollen.

If the stigma is not receptive at the time (as it usually is not), the desired pollen is not applied at once. The bag may be removed from time to time to allow of examination of the pistil, and when the stigma is mature, which is told by its glutinous or roughened appearance (148), the time for pollination has come.

286a. The flower may be covered with a grocer's common manilla bag, as in Fig. 234. The bag may be handily prepared by thrusting a string through the two flaps (as in Fig. 235) and tying it at one of the edges. If the bag is slightly moistened, it can be puckered more tightly about the stem of the plant. The time required for the stigma to mature varies from several hours to a few days.

287. When the stigma is ready, an unopened anther from the desired flower is crushed upon the finger-nail or a knife-blade and the pollen is

rubbed on the stigma by means of a tiny brush, the point of a knife-blade or a sliver of wood. The flower is again covered with the bag, which is allowed to remain for several days until all danger of other pollination is past.

287a. Care must be taken to completely cover the stigmatic surface with pollen, if possible. If one is making scientific experiments, it is well to cover the flowers which are to furnish the pollen from the time they are in bud, to make sure that no foreign pollen has been deposited on the anthers (and thereby become mixed with the desired pollen) by wind or insects.

288. When flowers are in dense clusters it is impossible to cover one of them with a bag, and the operator may not care to pollinate the entire lot; and, moreover, only a part of the flowers in most plants may be expected to mature perfect seeds. (See, for example, the apple cluster in Fig. 46.) In such cases, a few of the flowers should be prepared for crossing, and all the remaining buds should be removed. In composites, all the flowers but half a dozen or dozen may be removed from the head. The crossing of flowers is generally not difficult if one has patience and deft fingers, but every

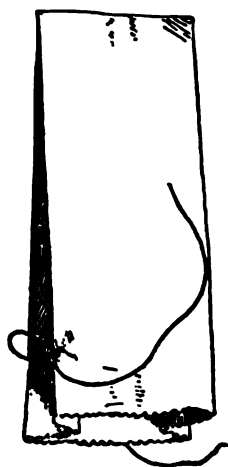


FIG. 235.

Bag prepared for use.

care should be taken that no foreign pollen reaches the stigma.

SUGGESTIONS.—Each pupil should cross a few plants and save the seeds and sow them, keeping records of the relative heights, productiveness (number of flowers or fruits), color and other features of the parents and offspring. He should not be discouraged if many of the crossings fail, for the best operators often fail to "set" more than half of the flowers. Fuller directions for this operation, and also discussions of the philosophy of crossing, may be found in Bailey's "Plant-Breeding."

PART IV

STUDIES OF THE FRUCTIFICATION

XLVII. THE AKENE

289. We know that the office of the flower is to produce seeds with which to perpetuate the plant. The seeds are borne in various numbers and modes. In the *hepatica* (Fig. 132) there is a head or bunch of pistils; in the tulip there is only one pistil, but it is a compound of three carpels. We know that a flower may contain one simple pistil, one variously compounded pistil, or a number of simple pistils; and these pistils or carpels may contain one or many seeds.

290. One of the pistils of the *hepatica*, cut in two lengthwise, is shown in Fig. 141. The pistil is not only simple (comprising but a single carpel), but it is 1-seeded. Furthermore, it does not dehisce, or split open, but the ovary and the ovule grow into a single seed-like body. Such a single-seeded, dry, indehiscent structure is known as an *akene* (or *achenium*).

291. The seed is the ripened ovule. The seed is enclosed within the walls of the ripened ovary, and the ripened ovary or seed-vessel is the pericarp. The entire structure, comprising seed, pericarp, and the parts which may be inseparably grown to them, is the fruit.



FIG. 236.
Tailed akene of
clematis.

291a. The term fruit is in common use in botanical writings. It is sometimes used to designate only the ripened pistil (the pericarp and seeds), but better usage allows it to stand for the pericarp and whatever other structure (as calyx or receptacle) may be organically united with it. The horticulturist uses it more loosely, for any edible product

which is more or less intimately associated in its development with the flower. Confusion, therefore, arises; and since the word belonged first to general literature and to horticulture, which, therefore, have prior rights, it is a pity that it was ever given a technical botanical meaning. But there is no good technical word which can be substituted for it.

292. In the hepatica akene, the growth since flowering time has been confined to the pericarp and seed. Fig. 236 is the akene of a clematis, which, like the hepatica, is one of the crowfoot family or Ranunculaceæ. The tail-like part is the enlarged and elongated style. It is seen, therefore, that



FIG. 237.

Burs of hound's-tongue. Twice natural size.

even the style may persist and enter into the make-up of the fruit.

293. In these instances, the akene is a ripened superior ovary. If one turns again to the dandelion, however (Fig. 171), he finds a 1-seeded dry ovary, with the calyx (or pappus) springing from its top. This kind of fruit is characteristic of the composite family, and we have already observed several forms of it (Obs. xxxiii.).



FIG. 238.

Flower of strawberry.

293a. This particular type of akene-fruit is known as a cyp-sela, but the term is little used. The fruit of the grasses and cereal grains is also an akene-like body which (as a grain of wheat or the "meat" of an oat) is technically known as a caryopsis; here the seed is covered by the adherent walls of the ovary.

What is the structure of the "stick-tight" or bur, in Fig. 237? The plant is a common and familiar weed. The pistil of the mint (Fig. 140) may aid in the solution.

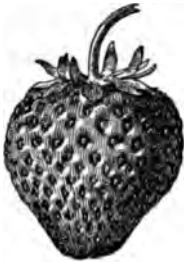


FIG. 239.

Normal fruit of
strawberry.

294. Let the pupil examine a flower of the strawberry (Fig. 238).

It is quadriserial and polypetalous. As in the hepatica, the pistils are many and 1-ovuled, and they form a cluster or head in the center of the flower, as akenes are very apt to do.

294a. In the plan of the flower, the hepatica and strawberry are much alike, and yet they belong to different families. The

strawberry is one of the rose family. We have already seen (172, 173) that the hepatica is held to be apetalous, and the strawberry flower is reinforced (171). A most important gross difference between the two, however, is the fact that the hepatica is hypogynous, while the strawberry is essentially perigynous (170).

295. In a short time (let the pupil determine how long), a strawberry (Fig. 239) stands where the flower was. There was no obvious promise of such a structure in the flower. If we cut the strawberry across, we find no seeds in it, and it cannot, therefore, be a pistil. The numerous pistils which we saw in the flower are borne upon the outside of the strawberry, and are akenes. The edible part, therefore, must be a receptacle.



Fig. 240.

Strawberry injured
by frost.

296. The pupil sees that the strawberry in Fig. 239 is symmetrically developed, both as to form and as to number and arrangement of akenes. Fig. 240 is a malformed or "nubbin" strawberry. If the pupil were to examine such berries, he would find that a deformity in any portion of the edible receptacle is generally associated with non-development of the akenes.

SUGGESTIONS.—Now determine whether failure of the akenes in the strawberry is the cause of the malformation, or whether an injury to the receptacle is the cause of both the malformation and the failure of the akenes. Before fertilization takes place, cut the styles from several of the pistils at one point, and see if the

strawberry does not become a "nubbin"; or watch the effect of frost when the plants are in flower. The pupil will be interested in Fig. 241, which shows a cluster of blackberries which was nipped by frost when in flower. Most of the pistils were killed (for pistils are very susceptible to frost), but two of them, NN, developed fruits. Perhaps "nubbin" strawberries, blackberries and raspberries can be produced also by withholding pollen from some of the pistils. It is not unusual to find curious monstrosities of the strawberry. Fig. 242 is one, showing a cluster of leaves springing from the apex, thus suggesting the stem character of the strawberry fruit. The berry is cut in two lengthwise.

XLVIII. THE DRUPE

297. A raspberry is shown in Fig. 243. Each of the little fleshy parts in the berry is found to contain a seed, and each one bears the remains of a style. Each one, therefore, must be a simple pistil. The parts are indehiscent, and they differ from an akene chiefly in the fact that the outer part is fleshy, rather than dry and thin. Such fleshy little akene-like fruits are called drupelets.

298. The edible part of the raspberry, then, is homologous with the akenes of the strawberry; and the core, *s*, which remains



FIG. 241.

Frost-injured black-
berries.

upon the bush when the raspberry is picked, is the receptacle. The pupil should now explain the morphology of the blackberry.



FIG. 242.

Proliferous fruit of strawberry.

299. The pupil will now be interested in peaches, apricots, plums and cherries. He has seen the structure of the flower in Figs. 47, 48, 144. There is a single superior pistil. The petals and stamens are perigynous, and both fall soon after fertilization has taken place. The gamosepalous calyx (or receptacle-tube, 170) persists for a time, but finally breaks away at the base, and the ring gradually works off over the top of the swelling fruit (Fig. 244). In these fruits, therefore, only the ovary and its contents persist and ripen into the fruit.

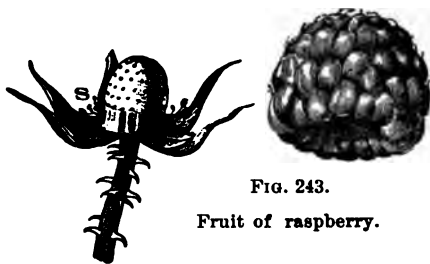


FIG. 243.

Fruit of raspberry.

299a. Why does the ring slip off, rather than break in two? Do peaches, cherries and plums behave in the same way? Are there similar rings on young apple and pear fruits?

300. As the fruit continues to grow (Figs. 31,

245), it becomes greatly thickened and fleshy; but the interior develops a hard stone or pit. This pit (or putamen, as it is sometimes called in botanical writings) contains a distinct and separate seed, so that it is clear that the walls of the pit could not have developed from the ovule. The entire integument, then, must be pericarp. In such kinds of differentiation of the walls of the peri-

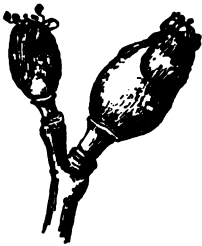


FIG. 244.

Young apricot fruits
shedding the ring.

carp, the outer soft portion is commonly called the exocarp (or sarcocarp), and the inner firm portion (the pit) is called the endocarp.

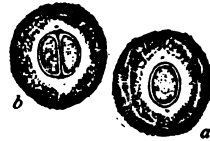


FIG. 245.

Cross-section of young
apricot fruits.

An entire fruit of this character,—with a pit or stone and a fleshy covering,—is a drupe or stone fruit; and it differs from the drupelet only in the fact that it is larger and is borne singly.

301. If one were to cut across young apricots, peaches or plums, he would find that the stone is for a long time thin and soft. He would also find, as a rule, only one seed, as at *a*, Fig. 245, and we know that a peach pit or plum pit generally has but one "meat." Now and then he may find two seeds (*b*), either one or both of which may develop. Very often one of these seeds is

seen to be smaller than the other, and the pupil may infer that it will be crowded out. The fact is that the ovary of peaches, apricots, plums and cherries contains two ovules, but one of them commonly aborts; that is, it is crowded out, and no remains of it may be seen in the ripened fruit. When both ovules get an equal start, both may persist, and the fruit is "double-meated." We may wonder if, in the process of time, one ovule will be entirely lost.



FIG. 246.

Monstrous pistils of peach.

302. While some plants bear many pistils in each flower and others only one, we must not conclude therefrom that these features are invariable. We have already learned that any structure or habit may be broken or changed upon occasion. Fig. 246 shows a monstrosity of the peach, five good pistils having formed in one flower. The probability is that only one or two of them would have ripened. If two or more should have persisted, they probably would have coalesced, and a double or triple peach would have been the result. This duplication of pistils is not very rare in the

peach. It is no doubt a doubling by increase of parts, as we have seen to take place in some perianths (233). We might speculate as to whether this doubling may be a reversion to some ancestral form, or an indication that multiple pistils might become an established character of the peach upon occasion; or it may be an incidental variation of no significance in the evolution of the plant. It is certainly evidence, however, that the peach is capable of wide variation in its essential organ.

SUGGESTIONS.—The pupil should endeavor to make collections of drupaceous fruits, and should study their sizes, colors and shapes, and especially should notice their number as compared with the flowers which bore them. He may be interested to cut them in two at various stages of growth, to determine at what epoch the most rapid thickening of the exocarp takes place. The fruit-grower thinks that the pit grows early in the season and the flesh late in the season: is this true?

XLIX. SIMPLE PODS

303. The columbine (which we saw in Fig. 227) has five pistils, and the fruit is like that shown in Fig. 247. One of them has opened at *b*, and several seeds have been discharged. In other words, this fruit is dehiscent, whereas the akene is indehiscent. It is approximately correct to say

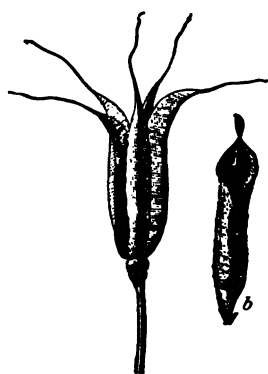


FIG. 247.

Follicles of columbine.

that one-seeded fruits are indehiscent, but many-seeded fruits are usually dehiscent. That is, the seed of the akene and drupe is liberated from the outer covering by rupture or decay of the pericarp.

304. The dehiscence, or opening, of the fruits of the columbine takes place along the inner edge, as in *b*. We have seen that carpels are akin to leaves. It requires little imagination to suggest that the carpel of the columbine may represent a leaf rolled inward, and that it splits along the union of the two edges; and this supposition is borne out by much direct evidence. The front or upper side of the leaf-carpel faces inward and the back or under side, or mid-rib, faces outward. The front is known as the ventral side, and the back as the dorsal side.

304a. The beginner cannot expect to prove that the carpel has actually been developed from a leaf, although he has seen much evidence to show that the parts of the flower may be transformed foliage leaves (recall Obs. xxxvii). The important point to remember here is that floral members and leaves are comparable, and that the best way in which to define and to understand the carpel is to liken it to a transformed leaf.

305. The carpels of the columbine open by the ventral side or suture. The different carpels are not united, so that the plant produces five fruits from each flower. The columbine is, therefore, said to be apocarpous (the carpels not organically united), whereas pistils made up of several carpels—that is, compound pistils—are said to be syncarpous

305a. A suture is a juncture, seam, or place of union. Does the columbine always produce five pods, or may some of the pistils perish in the struggle for existence?

305b. Dry dehiscent fruits or pericarps are known under the general name of pods. A pod which opens by the ventral suture alone, as the columbine does, is a foliicle.

306. A bean pod is shown in Fig. 248. It differs from the columbine pod in the fact that it opens on both edges,—on both the ventral and dorsal sutures. This kind of a pod is a legume.

306a. Do all pods of peas and beans open by both sutures? Examine the garden peas. In order to determine the manner of dehiscence of any pod, examine it when fully ripe and dry.

306b. When a fruit dehisces into two or more parts, the sepa-

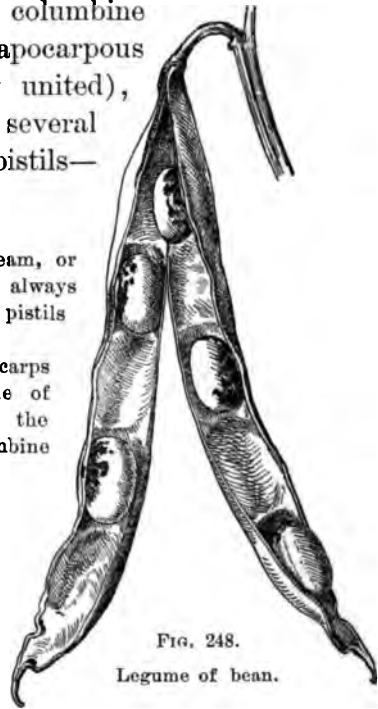


FIG. 248.
Legume of bean.

able portions are known as valves. The legume is, therefore, 2-valved.



FIG. 249.

Jeffersonia.
(See Fig. 86.)

307. The pupil has seen the flower and pistil of the mustard (Figs. 133, 134). Inasmuch as this pod is 2-carpelled, with a partition extending from side to side, we should look for a different type of dehiscence from that occurring in the simple follicle and the legume. The mature pod in Fig. 135 shows the method of dehiscence, the valves breaking away at the base and leaving the placentæ and partition.

307a. This mustard fruit is characteristic of the family,—the cabbages, turnips, radishes, wallflowers, stocks, alyssum, and the like. When the pod is prominently longer than broad, as in the mustard, it is known as a silique, but when broader than long, as in the shepherd's purse, it is called a silicle. The mustard fruit is 2-loculed by a false partition which stretches across it,—that is, by a partition which is not a part of the structure of the young ovary; but the pod is 2-carpelled, as may be seen by the two marginal placentæ (which are joined by the partition). While the mustard fruit is compound, it might be mistaken, therefore, for a simple pod.

308. It is not necessary that all pods open longitudinally. There are many kinds of dehiscence, and some of them follow no definite method. An occasional type is such as one finds in the purslane (or "pussley"), door-yard plantain, henbane, and one of the pigweeds or red-root, in

which the top of the pod comes off, sometimes like a cover and sometimes like a hinged lid. This type of dehiscence is described as circumscissile, and such a pod is a pyxis.

309. A modification of this type of dehiscence is seen in the jeffersonia or rheumatism-root (Fig. 249), in which the pod breaks half around near its apex, and the upper portion or valve forms a lid. Some pods open by holes or pores in the top, as those of the poppy and water lilies. All these types are examples of apical dehiscence. Not all the pods mentioned in these two paragraphs are simple.



FIG. 250.

Pod of lilac.

L. COMPOUND PODS

310. If the carpels or follicles of the columbine (Fig. 247) were united more or less completely, we should have a compound pod, or a capsule.

311. If these carpels were united to their tops, the primary dehiscence could not well take place along the ventral sutures. The probability is that the carpels would open on the back or outward sides, or by first separating from each other.

312. The seed-pod or capsule of the lilac (which remains on the bush all winter) is shown in

Fig. 250. It is obviously 2-loculed, but the capsule has split down each side midway between the partitions or dissepiments. That is, each valve contains half of two carpels.



FIG. 251.

Pod of castor-oil bean after dehiscence.

313. In the capsule of the castor-oil bean (Fig. 251), the three carpels have separated from each other, and each carpel must dehisce



FIG. 252.

Dehiscence of azalea.

before the seed is liberated. The outer prickly coat breaks away, usually in six pieces. Two of the lobed carpels are designated by *a a*. A similar dehiscence has taken place in the azalea (Fig. 252), but here the seeds are liberated by the primary splitting of the pod, and the central shaft, with which the carpels were united, remains. The dissepiments are seen on the very edges of the five valves. Each valve in the castor-bean and azalea represents a complete carpel.

313a. These two methods of dehiscence of compound pods (or capsules) are characteristic types. The former (312) is known as loculicidal dehiscence,—the splitting of the walls between the carpellar dissepiments, and directly opening up the locules. The latter method (313) is septicidal,—the breaking up of the capsule into its component carpels, or at least into parts which represent these carpels; and, in some cases, each carpel again dehisces before the seeds can be discharged.

313b. The pupil can now determine the dehiscence in Figs. 253 and 254, and of other pods which he may find attached to plants in winter or early spring. The characters of the dehiscence usually are not obscured by this long period of weathering. He will be interested in examining the pods of blue-flags, tulips, lilies, mulleins, toad-flax, phlox, datura or jimson-weed, canna, St. John's-wort, and many other common things.

313c. Those living in the South will be interested in studying the cotton (Fig. 255). The fruit is a capsule, splitting loculicidally, and the seeds are covered with the fiber, which is woven into fabrics. The picture shows that the pod is furnished with an involucrel. How and where are the seeds attached? How many seeds are there in each fruit? How is the cotton packed away? How many carpels are there, and does the number vary in different fruits?

314. A pod of the morning-glory is shown in Fig. 256. The dehiscence is essentially septicidal,



FIG. 253.
Pod of shrubby
hibiscus.

but the outside wall of the capsule breaks away from the dissepiment. The falling seeds (two in each locule) are at *a a*, and a valve at *v*. This is septifragal dehiscence.

Septifragal dehiscence (the separation of the valves from the partitions) may occur in either loculicidal or septicidal pods. The im-



FIG. 254.
Pod of day-lily or funkia.

tion of the valves from the partitions) may occur in either loculicidal or septicidal pods. The im-

portant point is, that while there are many capsules in which the dehiscence is so undisguised

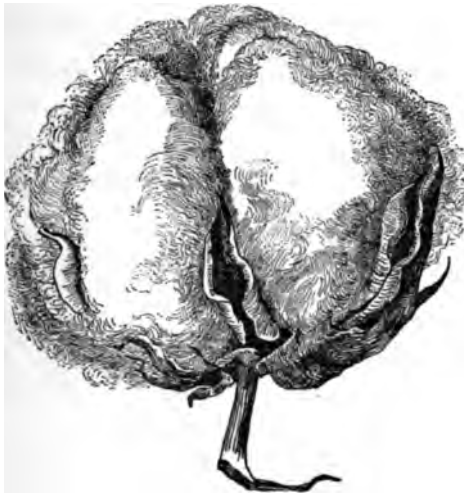


FIG. 255.
Boll of cotton.

that we can express it accurately by a single word, there are many others in which the mode is intermediate or even ill-defined.

315. The pod of the mignonette (Fig. 257) is familiar. It is a pouch with a single cavity, and is open at the top. If a pod is examined, the seeds will be found attached to the walls in several more or

less definite placentæ. We suspect, therefore, that the fruit is really made up of more than one carpel, notwithstanding its apparent simplicity. If, now, we go back to the flower, we find the pistil closed, and as many sessile stigmas as there are to be lobes or angles on the mouth of the pod. The dissepiments are wanting, but there are homological reasons,



FIG. 256.
Capsule of morning-glory.

other than the several stigmas and the well-marked placentæ, for believing that the pistil is compound. We are again impressed with the infinite variety in details, and with the importance of considering the meaning of even obscure features when attempting to interpret any structure.

315a. The pupil will find much to interest him in the inconspicuous flowers of the mignonette; and the plant is one of the easiest to grow.

316. A pod of the common garden balsam is seen in Fig. 258. It is 5-carpelled, but the partitions remain very thin, and are often nearly obsolete in the mature fruit. The large black seeds are borne upon axile placentæ. When the pod is fully ripe, the five valves break apart and curl up elastically, the central column being torn away at the same time and the seeds scattered.



FIG. 257.
Pod of mignonette.

A pod which has been thus shattered is seen in Fig. 259. The dehiscence of the fruit, therefore, may be the means of forcefully disseminating the seeds.



FIG. 258.

Pod of balsam.

316a. The balsam is very easily grown from seeds. The capsules mature in abundance in the fall. If one desires to see them explode, he may pinch the noses of the fully ripe ones as they

hang on the plant; or he may lay them on a table and apply a light pressure with the fingers. Ripe pods dropped upon the walk are shattered the instant they strike. Two wild plants inhabiting low places, closely allied to the balsam, are known as jewel-weeds, and bear curiously sensitive pods.

316*b*. The fruits of many plants cast their seeds forcibly, often throwing them a distance of several feet. The oxalis and violet may be observed; also wistaria, jack bean (now grown in the South),



FIG. 259.

Explosion of the
balsam pod.



FIG. 260.

Fruit of balloon-vine,
or *cardiospermum*.

and some dry-podded garden peas and beans. Ripe pods of Japanese wistaria (a leguminous climber much used for porches and arbors) explode with great force when laid upon a table in a warm room. (See 331.)

317. The curious papery-inflated fruit of the balloon vine, or heartseed of the gardens (and native in the southwestern states), is shown in Fig. 260. It is 3-loculed, with a single globular

seed borne midway up the placenta of each locule. It is indehiscent, the seed being liberated by the decay of the walls of the fruit. It would appear, therefore, that this fruit could not be called a pod or a capsule, since the definition of those fruits includes dehiscence; but this fruit is so like a pod in its general structure and in being dry,



FIG. 261.

Four-sided and tardily-dehiscent legumes of *daubentonia*.

that it is commonly called a pod. There is no distinctive technical name for this type of fruit.

317a. Even in the Leguminosæ, or pea family (240), which produces the fruit taken as the type of the simple pod or legume, there are plants which produce practically indehiscent pods. Observe the honey locust, clover, peanut; also the *daubentonia*, in Fig. 261.

318. We have now seen (307) that the compound ovary of the mustard imitates a simple ovary (the partition being a false one), and the compound pod

of the mignonette is perfectly 1-loculed. We have also observed the various and sometimes undefinable dehiscence of pods, and have found that some fruits which are so much like pods that they are called pods by botanists are wholly indehiscent, and that even legumes may be indehiscent. We are thus impressed with the fact that names and definitions are merely convenient means of designating a few of the most pronounced features of plants, and do not necessarily represent structures which are typical or fundamental in the plant kingdom.

SUGGESTIONS.—We will now be interested in finding non-typical, or, rather, undefined, methods of dehiscence. We should also look for gradations between simple and compound capsular fruits. One of the best examples is to compare the simple follicles of columbine (Fig. 247) or larkspur with the loosely compound pods or capsules of the closely related nigella, or love-in-a-mist. The nigella is an easily grown annual, and seeds may be secured from any seedsman. It is an anomaly in the crowfoot family, because its follicles are grown together for the greater part of their length, making a true capsule.

LI. KEY-FRUIT

319. The pupil's attention has been directed to the flowers of the maple (Fig. 211). If he were to examine the ovary in a maple flower, he would find it to be 2-lobed and 2-loculed, with two ovules

in each locule. Mature fruits of maples are seen in Figs. 262 and 263. Each lobe has grown into a long, winged body, with only one seed, and the twin fruit suggests a pair of saddle-bags. Dry indehiscent winged fruits are known under the general name of key-fruit or samara.

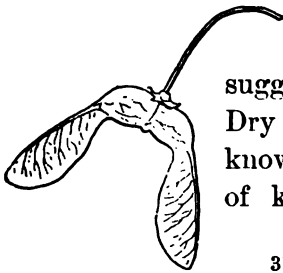


FIG. 262.
Key of
sugar maple.

319a. The pupil should determine if the wings of the maple fruit serve any purpose in distributing and planting the seed. How do the fruits behave when torn from the tree by wind? In what position do the fruits strike the ground? If the pupil has access to a large sugar maple tree which produced a good crop of fruit, let him examine the ground about the tree very early in the spring, in the endeavor to find the seeds. If the ground is loose or cultivated, the planting operations will be more conspicuous and interesting.

319b. The pupil can train his eye in the attempt to distinguish the different kinds of maples by means of their fruits. The fruits of two kinds are shown in the pictures; and a raceme of the forming fruits of negundo or box-elder (which is very closely allied to the maples) is shown in Fig. 264. Is the inflorescence of the negundo terminal or co-terminal (55)?

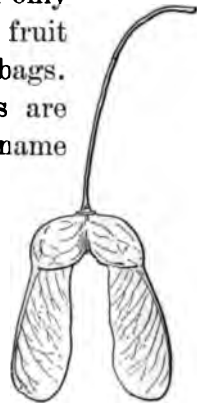


Fig. 263.
Black maple.

320. Another type of samara is that of the hop-tree or shrub-trefoil (Fig. 265), a large bush or very small tree, with trifoliate leaves, which is widely distributed over the country. In this case, the fruit is also 2-loculed, but it is winged

all around. In other words, there is no particular form of fruit which is typical of the samara.

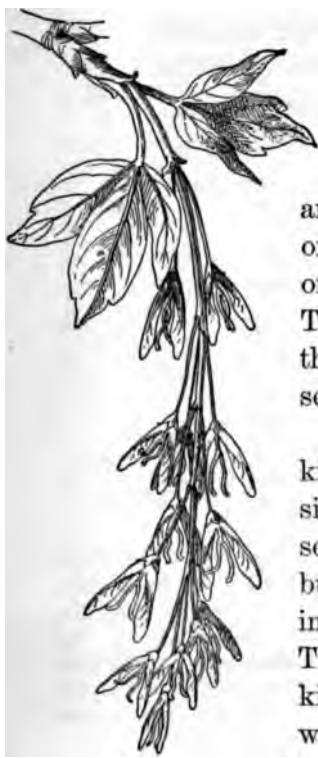


FIG. 264.

Box-elder.

321. Samaras of two of the common ashes are shown in Figs. 266 and 267. In these trees, the fruit is a cylindrical shaft provided with a wing, and the extent of this wing is one of the distinguishing marks of the different kinds of ash. The ovary is 2-carpelled. Are the fruits always or ever 2-seeded?

322. The fruits of various kinds of elms are shown, natural size, in Figs. 268-272. They resemble the fruit of the hop-tree, but differ in being 1-loculed and in other more technical characters. The pictures represent all the kinds of elms which the pupil will find in the United States outside of the Rio Grande region (except a few introduced species in gardens). Now let him determine the kinds which he may meet, and match with them the leaves and buds. The elm fruits mature in very early spring.

SUGGESTIONS.—In making such studies as those recommended in the last paragraph, both teacher and pupil should consider that



Fig. 265.

Samara of hop-tree.

mere identification is not the end to be sought. It is always a satisfaction to know the names of plants, but the important results, from the educational point of view, are the awakening of sympathy with natural objects, the sharpening of the powers of observation, and the strengthening of the faculty of reasoning from the object to laws and principles. These results are obtained most readily by studies of contrasts and comparisons. With very young pupils, the objects should be few, perhaps not more than two or three; but the numbers and

range of objects selected for comparison may increase rapidly with the progress of the scholar.



Fig. 266.

Key of white ash.

LII. BERRIES



Fig. 267.

Key of black ash.

323. We have seen the grape flower in Fig. 208. The calyx is almost obsolete, and the petals and stamens soon fall away. The pistil alone remains, and this ripens into a berry, as seen in Fig. 273.

The ovary is 2-loculed, and the locules are 2-ovuled. Is the grape always 4-seeded? There is nothing

about the pistil of the grape to show that it will become a berry and not a capsule. That is,



Fig. 268.

Key of common American elm.

the nature of the fruit as to substance, size or dehiscence cannot be determined from an examination of the pistil.

323a. A berry, in botanical language, is any several- or many-seeded fruit which is more or less soft and juicy throughout. As commonly, and likewise properly, used, the word designates any

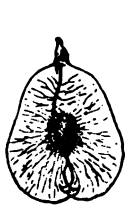


FIG. 269.

Fruit of slippery
elm.



FIG. 270.

Cork elm.



FIG. 271.

Fruit of wahoo
elm.



FIG. 272.

Scotch elm.
Cultivated.

small, pulpy seed-fruit (using the word fruit in its horticultural significance). In the horticultural or common-language sense, strawberries and blackberries are berries, but in the botanical sense grapes, currants, gooseberries, tomatoes and oranges are berries. The word is commonly used in these two meanings without much confusion arising, but if it should be necessary to choose between the two, it must be remembered that the botanist borrowed the word from common language, and that the latter, therefore, has prior rights.

324. If there are no constant differences in the pistils of baccate (or berry-bearing) and capsular fruits, then we should expect to find closely related plants upon which the two kinds of fruits are borne. The Solanaceæ, or nightshade family, may be selected

as an example. In the solanums proper, as the nightshade, potato, egg-plant, and also in the tomatoes, the fruits are berries; in the petunias, tobacco, and datura or jimson-weed (some kinds cultivated under the name of brugmansia), the fruits are capsular and dehiscent. In fact, in some of



FIG. 273.

Berries of Scuppernong grape.

the solanums, the berry is so hard and dry as to suggest a capsule. Berries and capsules are fundamentally not greatly unlike.

325. The red peppers or capsicums are members of the Solanaceæ, as determined by the characters of the flowers and by other features. The fruits are long in the Cayenne or Chili sorts (Fig. 113), but heart-like in the sweet peppers (Fig. 114), and tomato-shaped in other varieties. They are all more or less dry and firm in texture, especially the long forms. The Chili peppers would pass for

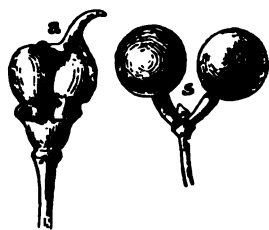


FIG. 274.

The curious behavior
of the blue cohosh.

Capsules except that they are indehiscent; and they are commonly described as dry berries. There is reason to believe that the dryness or the fleshiness of these fruits can be much intensified by the plant-breeder (Obs. lxxxi).

326. The hepatica is one of the Ranunculaceæ. So is the clematis. These are akene-bearing plants. The columbine, larkspur, marsh-marigold and pæony are of the same family, but are follicle-bearing plants. The nigella (Obs. l.) has the carpels united, or is capsular. The baneberry or



FIG. 275.

Corn-cockle.

cohosh (common in woods) and the golden-seal, or hydrastis, have berries or drupelets. All these are ranunculaceous plants. A still greater range is found in the rose family, of which one interesting case may be mentioned. The peach is esteemed for the pulp of the thickened pericarp, but the seed is inedible. The almond, which is so closely akin that there has been serious discussion as to whether it may not be the original form of the peach, is prized for its sweet seed, but the pericarp is hard and woody, and often dehisces like a pod! From all these examples it would seem that the nature or character of the fruit is a very specialized feature of the particular plant.

327. Berries are usually ripened pistils, or at least ovaries, but other parts of the floral structure may be inseparably united with the ovary in baccate fruits, or the berry may be even a ripened seed. An example of the latter is afforded by the blue cohosh, a small perennial herb growing in woods. The ovary is 2-ovuled, but the enlargement of these ovules,



FIG. 276.
Corn-cockle.

which grow upon stalks, soon ruptures the ovary (as at *a*, Fig. 274), and each seed becomes a blue drupe-like berry (*s*, Fig. 274)! The blue cohosh, or caulophyllum, is closely allied to the jeffersonia (Fig. 249), and the pupil may be able to trace resemblances in the dehiscence.



FIG. 277.
Flowers and
fruits of husk-tomato.

LIII.

REINFORCED FRUITS

328. We know that flowers are often reinforced by bracts and the like. (Obs. xxviii.) Fig. 275 is the flower of the common and handsome corn-cockle (see, also, Fig. 143). The corolla is convolute. The calyx, with its long sepal-like lobes, persists about the young pod (Fig. 276), but the lobes soon fall away, leaving the ripe capsule enwrapped in the calyx-tube.

328a. If the pupil has access to the corn-cockle (it is a common weed in wheat-fields), he should determine the make-up and

dehiscence of the pod, and observe whether the valves bear any relation to the number of styles.

329. The husk-tomato or ground-cherry (one kind is known as strawberry-tomato) is shown in Fig. 277. The flower, with its calyx a half smaller than the corolla, is at 8. The pistil is 2-loculed, and ripens into a true berry, very like a small tomato. The calyx, however, grows enormously (Nos. 9, 10). It is evident that the part which chiefly enlarges



FIG. 278.
Flower of agrimony.



FIG. 279.
Bur of agrimony.

is the tube and not the lobes. In the cockle and the husk-tomato, the calyx is not considered to be part of the fruit, because it is not organically united with the capsule or the berry, but merely encloses it.

329a. Seeds of three or four kinds of husk-tomato (or physalis) are sold by seedsmen, and the plants are easy to grow. Some of them are grown for the brilliant color of the great inflated calyx, and others for the edible berries.

330. The agrimony is a rather small herb of rich woods and tangles, bearing small yellow flow-

ers, one of which is shown (thrice natural size) in Fig. 278. The calyx is tubular or top-shaped,

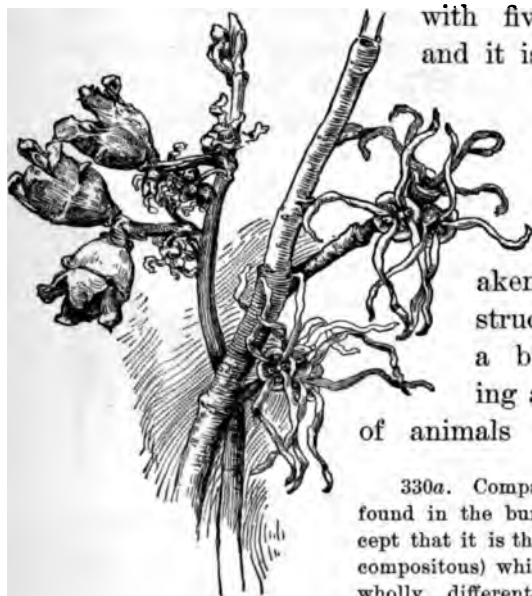


FIG. 280.

The witch-hazel.

with five spreading lobes, and it is beset with hooked bristles. After

flowering, the calyx-lobes close up and enclose the ovary with its two

akenes; and the whole structure is carried as a bur upon the clothing and upon the fleeces of animals (Fig. 279).

330a. Comparable structures may be found in the burdock and cockle-bur, except that it is the involucre (the flowers are compositous) which bears the bristles. A wholly different type of bur is the "stick-tight," shown in Fig. 237.

331. When October has come and the leaves are fallen, and the last golden-rods have faded, the witch-hazel (Fig. 280) uncurls its yellow ribbon-like petals, as if forgetful of the season. There are four of these petals and as many stamens, but four alternating scales suggest that other stamens are wanting. A brown calyx-cup, with four sepal-like lobes, hugs

the flower closely. The flowers are no sooner fertilized than the cold weather closes in. The petals wither, and the flower enters upon a long hibernation. In spring these flowers look as if the petals had just died, the lobes still persisting upon the calyx-cup and the two styles remain green and fresh on the downy ovary. The capsule slowly enlarges into a 2-loculed and 2-seeded nut-like fruit, the calyx-cup adhering firmly to its base. It splits loculicidally, and elastic tissues, probably released by hygroscopic action, throw the seeds a distance of several feet.



FIG. 281.

Young cocoa-nuts.

331a. Very hard fruits, like that of the witch-hazel, are popularly called nuts. In botanical usage, however, a nut is a hard and dry indehiscent 1-seeded fruit, which arises from a compound ovary by the suppression of all the ovules except one. By this definition acorns, beech-nuts, hickory-nuts, hazels and filberts are nuts.

331b. It is often asked why the witch-hazel blossoms in the fall. We do not know; but if a search were made of its genealogy, we might find some clew. If some plants are large and others small, and if some are trees and some are vines, to enable each to find a place and a way to live in the ever-increasing conflict of numbers, then it is not too much to suppose that some

bloom early and others bloom late in order to escape competition. This is only a generalization. The witch-hazel, like every



FIG. 282.

White oak.

other plant, must be patiently investigated for itself. It is not unique in its habit of autumn blooming. Residents in the Gulf states and California will recall the loquat (often wrongly called Japan plum), one of the rose family, which blooms from November until Christmas, and ripens its pleasant, acid fruits in the spring. The teacher may be interested in discussions on the philosophy of the flower seasons in *American Naturalist*, September, 1893, by Henry L. Clarke, and in *Essay XVII.*, in "The Survival of the Unlike."



FIG. 283.

Bur oak.

332. The edible part of the cocoa-nut is a seed.



FIG. 284.

Chestnut oak.

As it generally arrives in the market it is closely enveloped in a husk, which is formed from the pericarp. Fig. 281 shows young nuts, shortly after the flowers have fallen.

The nut, *a*, is enveloped with three petals and three sepals. These parts have enlarged somewhat in *b*, but the pericarp has greatly elongated. The floral envelopes are enlarged and spread by the growth of

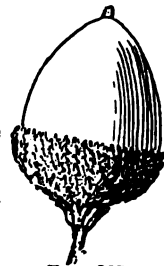


FIG. 285.

Swamp white oak.

the fruit, but they continue to be comparatively small, and remain upon the tree when the fruit is picked.

332a. Since the cocoa-nut is a dry indehiscent 1-seeded fruit, it might be likened to a gigantic akene. Structurally, however, it is more like a drupe, for the fibrous husk is formed from the outer part of the pericarp (or exocarp, 300), and the hard shell enclosing the meat is the inner part of the pericarp, or endocarp. Palm pistils are 3-carpelled, and in the cocoa-

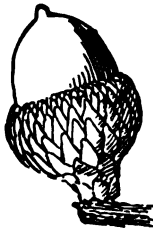


FIG. 286.
Scarlet oak.



FIG. 287.
Black oak.



FIG. 288.
Red oak.



FIG. 289.
Live oak.

nut tribe each carpel is 1-ovuled. The marks of the three carpels may be seen on the ripe nut, but only one ovule develops into a seed (408a).

333. In all the above instances, it is plain that the reinforcing structure is the perianth, usually a calyx. If the pupil will diligently examine the fruits of common herbs and bushes and trees, he will soon find that a persistent calyx is frequent.

LIV. REINFORCED FRUITS, CONCLUDED

334. Acorns are shown, about natural size, in Figs. 282-290. The nut itself is a pericarp contain-



FIG. 290.

An English oak, often
planted in this country.

ing a single seed. The ovary is really 6-ovuled, but only one ovule ripens into a seed. About the base of the pericarp is a scaly structure which is interpreted to be an involucre. The leaf-like structure of this cup (or cupule, whence the name of the oak and chestnut family, the *Cupuliferæ*) is apparent in some of the oaks like the bur oak (Fig. 283), in which the scales are much developed;

and it is especially demonstrated by the 2-leaved husks of the hazel and filbert, which are related plants.

334a. The pupil should determine what time elapses from blooming-time to the ripening of the acorn. This can be discovered by observing the ages of the wood (or twigs) upon which the flowers and the acorns are borne. He should compare, in this respect, the white oak tribes (including the live oak, chestnut oak and bur oak) and the black oak tribes (including the scarlet, red and black oak). The same oaks should be contrasted as to the position of the

abortive ovules. In some oaks, the abortive ovules are near the apex of the seed and in others near the base of it.

334*b*. In studying the oak the collector will often find peculiar swellings on the twigs and leaves. These are usually globular, and the largest of them, which are sometimes called "oak apples," are an inch in diameter. A cross-section shows a fibrous or rayed structure. These objects are galls, and are produced by insects, the grubs or larvæ of which live in them.

335. A hickory-nut is drawn, natural size, in Fig. 291. The nut is enclosed in a husk, which splits into four valves. We know that the edible meat of the hickory-nut is the seed, and the bony walls of the nut must be the pericarp, for the hardened remains of the style are persistent at its top. The fruit of the hickory is, therefore, dehiscent only to the pericarp. What is the morphology of the husk?

336. The black walnut and the butternut are closely allied to the hickory-nut, but the husk is indehiscent. The pistillate flowers of the butternut are shown in Fig. 292. There are two long stigmas exerted from a flask-shaped body. There are eight petal-like members upon this body, constituting a perianth, four of which, from their inside position, we may call petals and the outer four sepals. It is the flask-like body which ripens into the husk of the butternut, and



FIG. 291.
Hickory-nut.

there is difference of opinion as to its morphology. The walnuts and hickories are somewhat closely allied to the oaks, and it is held by



FIG. 292.

Pistillate flowers of butternut.

some that this husk is an involucre, although it has none of the obvious features (as scales) of an involucre. Others regard the flask-like body as a calyx-tube, and the four sepal-like parts as calyx lobes. In the hickory, the petals are wanting (Fig. 160), but the characteristics of the calyx-cup are very similar.

These two fruits show what a specialized feature dehiscence or indehiscence is; and they are particularly interesting as showing how much our interpretation of particular structures depends upon comparatively minor features.

337. The chestnut will now interest us. A mature bur is at Fig. 293. In this case there are two or more pistillate flowers (each with a well marked calyx) aggregated in a scaly and prickly involucre. Does one chestnut develop from each single flower? This involucre grows with the nuts, and becomes the 4-valved bur shown in the picture.

338. It is commonly assumed that these reinforcing structures are the result of adaptation,—that is, that they afford protection to the seed. It is no doubt true that they protect the seed, but it is by no means evident that this protection has been developed for the purpose of protection, or that it is primarily useful to the plant. The walnut fruits are so impervious that the seeds cannot grow unless under the most

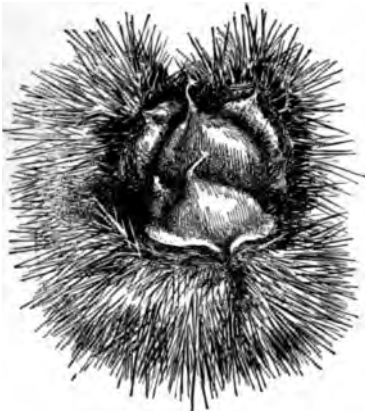


FIG. 293.
Chestnut bur.

favorable conditions. That is, there can be evidence adduced to show that these indehiscent husks and hard nuts are a detriment to the plant, as well as a benefit. Again, it is difficult to explain, upon the adaptation hypothesis, why the husks of hickories are dehiscent and those of walnuts are not, or, in fact, why these nuts have husks at all, whereas the many other fruits do not. Nor is it easy to

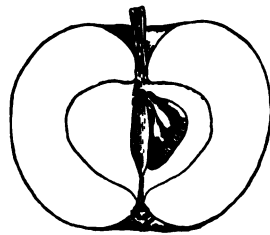


FIG. 294.
Section of an apple.

suppose that the cup of the acorn or the easily-dehiscent bur of the beech-nut was developed as a protection. The explanation lies farther back

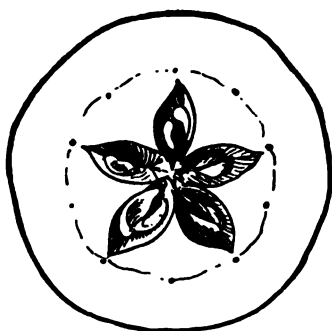


FIG. 295.

Section of an apple.

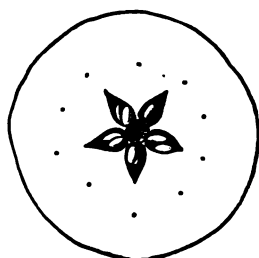


FIG. 296.

Section of an apple.

than any mere assumption of present needs or functions. Therefore,

339. The lesson is, that the pupil should first discover facts without reference to any preconceived explanation of them, and each fact should be interpreted chiefly upon its own evidence. (See 423.)

SUGGESTIONS.—The fruits of most of our forest trees belong to the various types or classes of fruits which we have now discussed. The teacher may think it worth the while to interest the pupils in making a complete collection of the fruits and seeds of the forest trees of the neighborhood, with the expectation, however, that the samples are to be of less value as a mere collection than as a means of awakening the pupils' interest in the collecting and in the subject (see "Suggestions," Obs. li.). They will also be useful in the school-room teaching, particularly in stormy weather, when fresh

collections cannot be made. The dry fruits may be preserved in glass jars, and the soft ones in alcohol diluted two to three times with water. Acorns are among the best fruits to study in a comparative way, because the kinds of oaks are many, the acorns themselves are variable, they keep indefinitely (if kept away from insects), and are pleasant to handle. Good hand-books to aid in the study of forest trees are, Apgar's "Trees of the Northern United States," Mathews' "Familiar Trees and Their Leaves," and Newhall's "Trees of Northeastern America," all profusely illustrated.

LV. APPLES AND THEIR LIKE

340. Consider the pictures of the apple flower, Fig. 139. The styles are five, showing that the pistil is compound. The ovules are attached near the base of the locules. The petals and stamens are apparently attached to the calyx-cup. The ovary seems to be wholly inferior.

341. Look at the developing apples, in Fig. 46. The styles and stamens persist at the top of the fruit; and so do the sepals.



FIG. 297.

The leaf on the apple.

342. A mature apple is



FIG. 298.

Medlar.

shown in longitudinal section in Fig. 294, and in crosswise section in Fig. 295. One of the enlarged locules is shown in the former, and the five (making the "core") are shown in the latter. In both of them there is a well-marked line separating the core from the flesh of the apple.

342a. Has the artist drawn these cores correctly? Perhaps Fig. 296 is liked better. Which way do the seeds point in an apple?

343. In Fig. 294, the bounding lines of the core join the stem below and meet the external apex above. At the top of the apple are still the remains of the sepals and the stamens.

344. This core must be the pistil, for it bears the seeds and has the five carpels answering to the five styles. We thought that in the flower the stamens were attached to the calyx. Their remains we have seen in the top of the mature apple (as hair-like bodies just below the sepals). Are they attached to the core portion or to the flesh portion?

345. If the remains of the stamens are attached to the flesh portion, it would seem to indicate that the flesh of the apple is derived from the calyx-tube; and this supposition is strengthened by the fact that only the core sits upon the stem (or upon what was the receptacle of the flower). From these considerations, it might seem

that the edible portion of the apple is thickened calyx-tube, with the spaces between the carpels filled up by the thickening walls of the pistil, and the line of demarcation between the pistil and calyx marked by the fibrous bundles and connecting tissue shown in the cross-sections (Figs. 295, 296).

346. The interpretation of the architecture of the apple is not so simple as it looks, however. Some botanists believe that the outer and fleshy portion represents calyx, but that the receptacle extends upwards and lines this calyx-tube (and thereby immediately invests the core), and bears the stamens on its summit. That is, the flower may

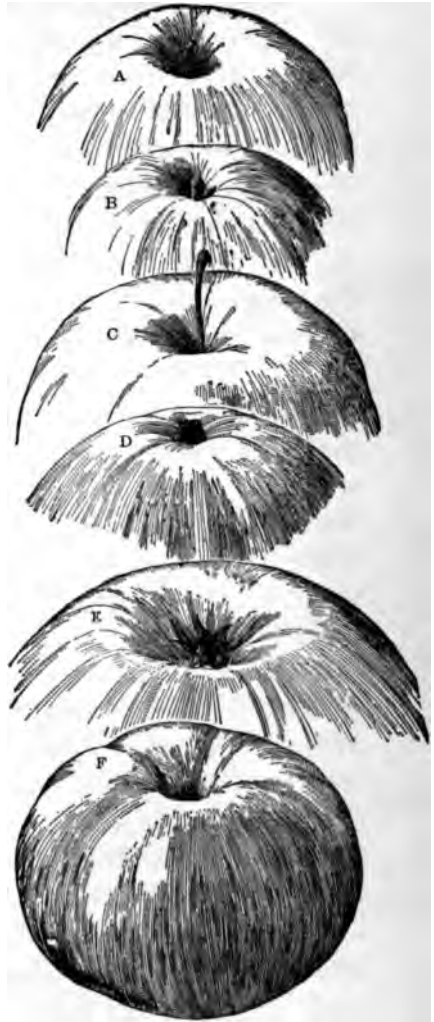


FIG. 299.

Variations in the apple.

be essentially hypogynous, rather than perigynous. But there is no really good reason for supposing that there is a receptacle-lining on the calyx-tube; and since many related plants are clearly perigynous, it might be inferred that the apple flower is also perigynous. This conception of the upward extension of the receptacle inside the calyx-tube has been the dominant interpretation of the apple, in this country.

347. If the receptacle extends upwards at all, beyond the base of the ovary, why not suppose that the entire flesh of the apple is thickened receptacle, and that the calyx and stamens are borne upon its rim? If the outer portion of the apple is receptacle, then it is essentially a stem structure. Fig. 297 shows a bract or minute leaf on the side of an apple (at A). This monstrosity is common. Since leaves are outgrowths of stems, it would seem to follow that this tell-tale leaf proves that the apple is receptacle, not calyx. But leaves are often outgrowths of leaves, as every observant gardener knows, for he has seen these little bract-like structures push out from the petals of flowers, from buds on the leaves of begonias and other plants (see Fig. 398). While the apple-bract raises a presumption that the flesh of the apple is derived from the stem (or receptacle), it really proves nothing. However, from all the

evidence to be obtained, the hypothesis that the flesh of the apple is receptacle is now gaining favor; but there is little evidence which can be called proof for any of the explanations. One of the best obvious evidences in support of this view is the fact that the lower part of the pear fruit often seems to be clearly pedicel.

347a. It is of little consequence to the beginner which, if any, of the three hypotheses is correct, but the discussion of them is of great value in awakening observation, and in suggesting the means of interpreting obscure structures. The pupil will also be impressed with the absorbing interest which may attach to the commonest objects when once his attention is called seriously to them.

348. Apples are known as pomes, and from this word is derived pomology, which is extended to mean the art and science of fruit-growing in general. Other pomes are pears, quinces, medlars, hawthorns, mountain ash, juneberries or shadberries. The medlar is a common apple-like or quince-like fruit of Europe, and it is frequently cultivated here. The picture in Fig. 298 was made from a specimen grown in New York. The long calyx-lobes still persist; so do the stamens, *a*. But the flesh does not cover the entire fruit, but leaves the five carpels bare at the top.

349. In pomological writings, the five leaf-like bodies on the apex of the apple are known as calyx. If the third hypothesis of the architecture

of the apple (347) is correct, then this horticultural terminology is also correct from the botanical standpoint; but if the apple is thickened calyx, then these bodies represent only a part of the calyx, and are really calyx-lobes. The character of this calyx is used in describing varieties of apples and pears. In D, Fig. 299, the calyx is said to be "closed"; in E it is "open." The calyx sits in a depression called a "basin." The basin is "shallow" in D, "deep" and "narrow" in F, and "broad" in E. The pedicel is known as the "stalk." The stalk is "long and slender" in C, and "short" in A and B. The stalk sits in a "cavity," which is described in essentially the same terms which are used for the basin.

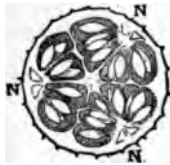


FIG. 300.

The gherkin.

SUGGESTIONS.—Compare the fruits of the apple, pear and quince, having all the above discussions in mind. Make comparisons of various kinds of apples, and attempt to designate the points of differences, giving attention to size, shape, color, basin, calyx, cavity, stalk, season of ripening, texture and flavor.

LVI. PUMPKINS AND SQUASHES

350. Squash flowers are shown in Figs. 161 and 162. The flowers are monœcious. The ovary is inferior to the calyx-lobes. The cucumber and gherkin (Figs. 163 and 164) belong to the same family; and so do the melons and gourds. The passion-flowers are close of kin.

351. When the fruits of squashes, melons and the like are very small, the seeds are seen to be borne upon three parietal placentæ; but these placentæ sometimes merge, or, in the watermelon, they may break away from the wall and appear as if axile. The pupil will surely recall the "core" of the watermelon. In some of the cucurbitous plants, these placentæ may be discerned when the fruits are ripe. They can be seen at N N N

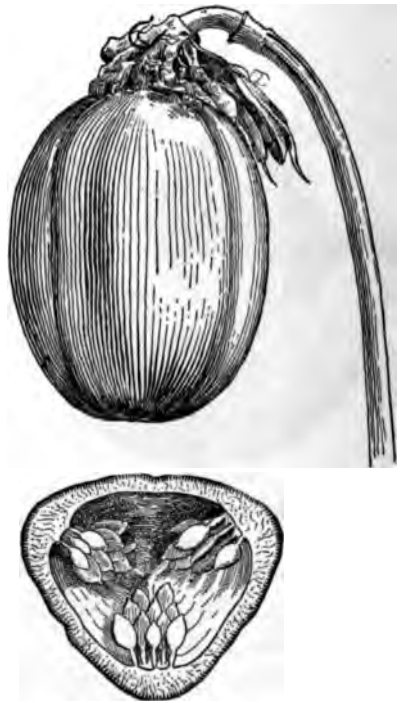


FIG. 301.

Fruit of the may-pop.

in Fig. 300; and still more plainly in the fruit of the may-pop (or *passiflora*) in Fig. 301.

351a. Do the ribs on the cucumber, gherkin and muskmelon bear any relation to the number and position of the placentæ? Does the same law hold in the may-pop?

352. Most persons know the turban squashes. Immature ones are shown in Figs. 302 and 303.



FIG. 302.

Young turban squash.

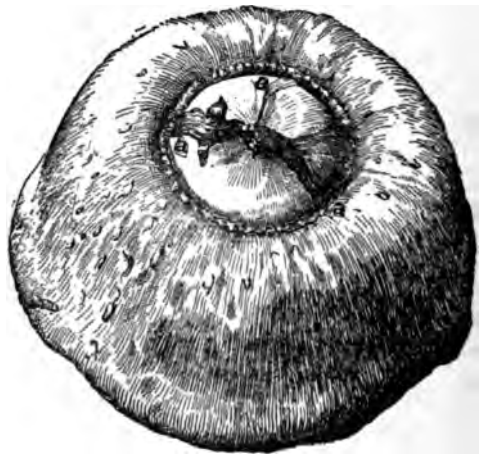


FIG. 303.

Young turban squash.

Persons are always asking why they grow so odd,—one squash inside another. We shall look, and try to find out.

353. A pistillate flower of a turban squash, cut lengthwise, is shown in Fig. 304. The corolla is cut off from *c* to *d*. This corolla is attached to

the outside of the forming fruit, while the pistil (with its six stigmatic surfaces) is the central structure.

354. Three or four weeks later, the squash has grown to the form shown in Fig. 303. The pistil still occupies the center, and the scar-like rim marks the insertion of the corolla and calyx-lobes. The corolla was not shed, but withered and persisted, perhaps being torn by the wind, and the widening pistil tore it asunder in shreds across the top of the fruit. Parts of the corolla, held in the crevice, are shown at *a a*. In Fig. 302, there has been a different result. The corolla withered and shrunk into a twisted mass (*e*), and became detached; but it was caught upon the protruding stigmas, and there it still hangs.

355. It still remains to determine what this outer portion is, which forms the shell and meat of the squash. We know that the inner part, or "inside squash," is pistil, because it bears the stigmas and because the corolla is attached beyond it. There is little evidence in the fruit itself to enable us to interpret its structure; but embryology shows that the squash is a hollow

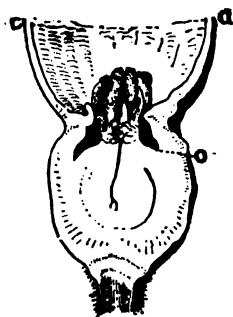


FIG. 304.

Portion of flower of
turban squash.

receptacle which, probably, is ordinarily closed at the top, but in the turban squashes it does not

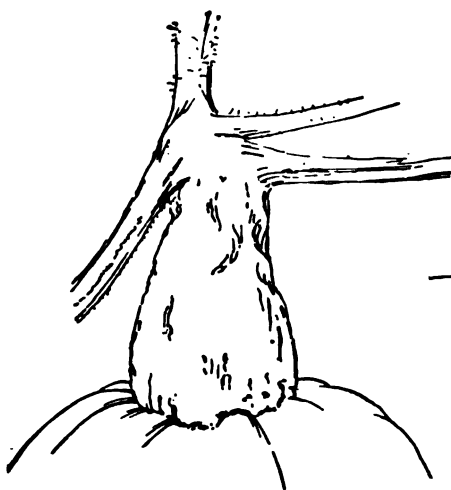


FIG. 305.

Stem of Hubbard squash.



FIG. 306.

Stem of Early Sugar pumpkin.

close up, and the carpels roof over the cavity. The squash, therefore, throws some light upon the structure of the pome.

356. The squash fruit is known as a pepo. Other pepo fruits, belonging to the Cucurbitaceæ, are pumpkins, gourds, cucumbers and melons.

SUGGESTIONS.—There are probably no fruits which are so endlessly variable as the pumpkins and squashes, and none, there-

fore, which are better adapted to a gross comparative study of forms, sizes and other characters. Persons are always asking how to tell a pumpkin from a squash. There is no well-defined usage of the words, but there are three types of fruits to which the names may be variously applied. These are well distinguished by means of foliage or other characters, but the most obvious differences to the inexperienced lie in the peduncles or fruit-stems. The fruits with cylindrical, spongy stems, which do not enlarge at the junction with the fruit, are squashes (Fig. 305). The Hubbard, turbans, Boston Marrow and Essex are of this type; also the mammoth fruits known as Chili pumpkins. Fig. 306 shows the hard angled stem of the pumpkin, as this term is understood in America. It includes the common field or pie pumpkin, and also

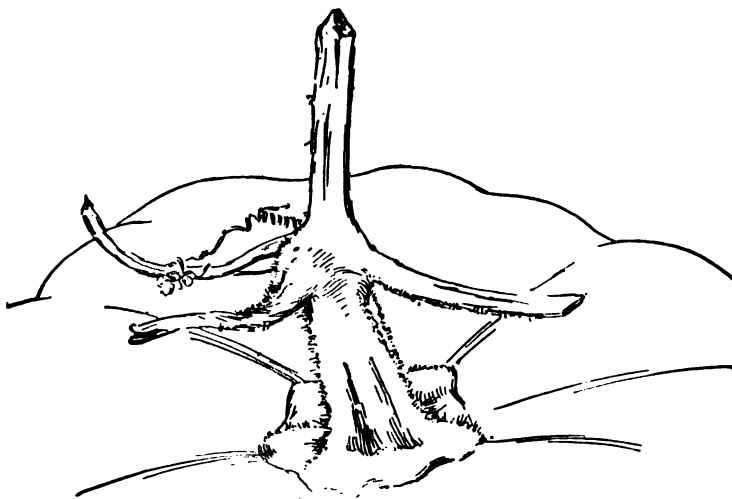


FIG. 307.

Stem of Large Cheese pumpkin.

the summer crookneck and patty-pan squashes. The types in Figs. 305 and 306 do not inter-cross. Fig. 307 shows another type of pumpkin, in which the angled stem enlarges as it joins the fruit. The so-called Japanese pumpkins, Cushaw pumpkins or squashes, and the winter or Canada crookneck, belong here.

LVII. TOMATOES AND ORANGES

357. The tomato was originally a 2-loculed fruit. Something very like the aboriginal type may be seen at the present day in the little Cherry tomato of the gardens.

358. Cultivation is high feeding. We supply the plant with more food by making the land

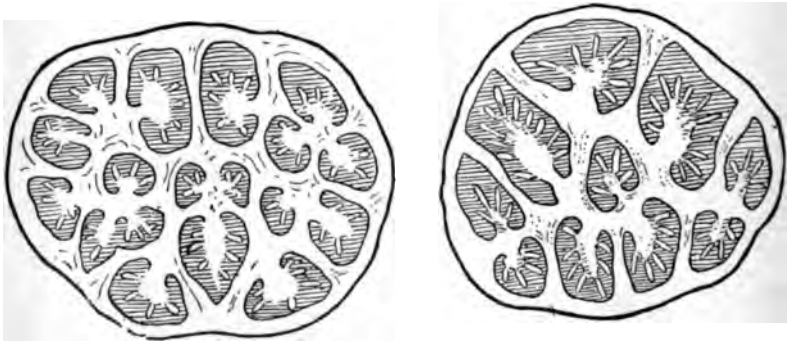


FIG. 308.

Sections of tomatoes.

richer and giving the plant more room; and we keep its enemies away. The plant must change. This change may be mere increase in bulk, or it may be that, plus other variation.

359. The tomato plant is much bigger than it used to be. The fruit is also bigger. Does the

increase in size of fruit come about by the mere expansion of the walls of the berry? If so, the fruit would be hollow, and useless.

360. Sections of common large tomatoes are seen in Fig. 308. There are many locules, and the partitions have become thick and firm.

361. The first great increase in size was accompanied by division of the two locules, and the fruit became angled or furrowed (or "rough," as gardeners say). These tomatoes are now unpopular, and "smooth" ones have been produced by

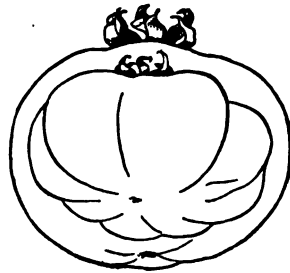


FIG. 309.

Old-time and new-time forms
of tomato fruit.

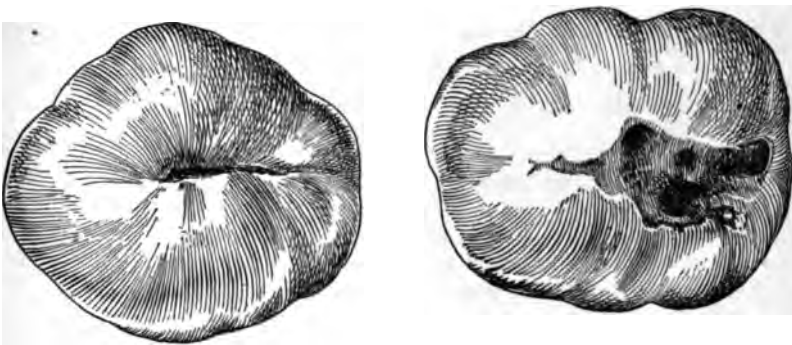


FIG. 310.

The mark showing the interposition of axile locules.

keeping the smoothest and saving seeds from them. The two forms are shown in Fig. 309.

362. With this elimination of the angled type of berry came the multiplication of the number of carpels and a relative diminution in their size. Some of these new carpels, not finding place near the



FIG. 311.

Turk's cap tomato.



FIG. 312.

Flower of navel orange.

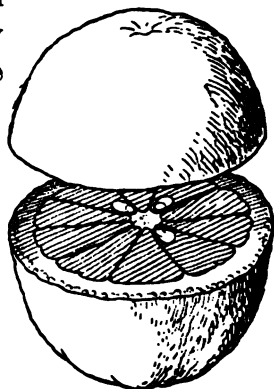


FIG. 313.

Common orange.

outside, thrust themselves into the middle of the berry. The fruit stretched and split on top much as the bark of a tree does (Fig. 310).

362a. The fruit-rot disease affects the high-bred tomatoes, but not the little Cherry types.

362b. The pupil will now be interested in tracing correlations between changes in fruit and foliage, in this evolution of the tomato; and the discussion in paragraph 137 may help him. The subject is presented in some detail in Bailey's "Survival of the Unlike."

363. A step farther, and some of these carpels may thrust themselves out of the top of the to-

mato; and then we have the Turk's Cap tomato (Fig. 311), which is sometimes grown as a curiosity.

363a. These many-loculed tomatoes may be comparatively seedless, and now and then a tomato is wholly so; but this seedlessness is not necessarily a result of the multiplication of the locules.

SUGGESTIONS.—The pupil should now explain the navel orange. The blossom is a normal orange flower, as shown in Fig. 312, producing pollen as other flowers do. Oranges are illustrated in Figs. 313 and 314; but the pupil will find better ones at the grocer's.

LVIII. MULBERRIES AND FIGS

364. Mulberries are monœcious, and the flowers are in catkins.

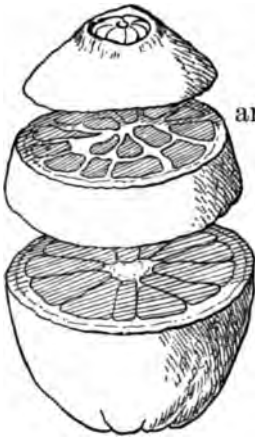


FIG. 314.

Navel orange.



FIG. 315.

Staminate catkin of mulberry.

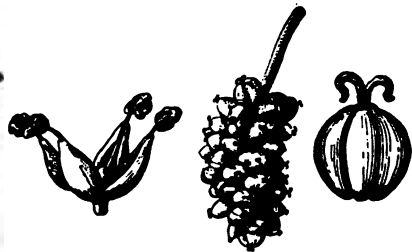


FIG. 316.

Pistillate catkin
of mulberry.

Fig. 315 is a staminate catkin. One of the flowers is enlarged. It has four sepals (for the flowers are apetalous), which are involute about the fila-



FIG. 317.

Mulberry fruit.

ments. A gland-like body in the center suggests a rudiment of a pistil.

365. The pistillate catkin is shown in Fig. 316. The flower has two styles, and four sepals which adhere closely to the ovary.

366. A mulberry fruit is shown in Fig. 317. It is composed of as many parts as there were pistils in the pistillate catkin. The stigmas seem to have disappeared, but the sepals have persisted; in fact, it is the thickened and fleshy sepals which comprise most of the edible part of the fruit.

The mulberry fruit, therefore, is an entire flower-cluster.



FIG. 318.

Fruits of fig.

366a. The mulberry is an example of what is called a multiple or collective fruit. Look at the pineapple.

366b. A mulberry looks like a blackberry. How do they differ?

367. Figs are shown in Fig. 318. They arise from the axils of leaves, as normal branches do. Each fig is an obo-

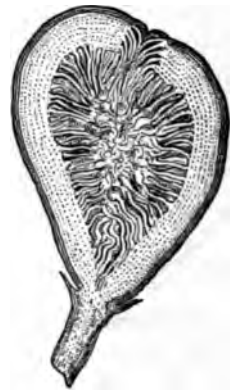


FIG. 319.

Fruit of fig in section.

void body with a hole in the top. The pupil will be puzzled by it, for the fig seems to be neither perianth nor pistil.

368. If a young fig were cut across (Fig. 319), it would be seen to contain numerous flowers (both staminate and pistillate) upon the inside. Each of the pistillate flowers ripens a little akene. The fig is, therefore, a receptacle lined with flowers, and the receptacle comprises most of the edible portion.

369. The fig and mulberry are closely allied. They belong to the same natural family. The plan and structure of the flowers are very similar. They both produce multiple or collective fruits, the entire flower becoming more or less thickened and fleshy; but in the one the flowers are borne upon the inside of an enormously-developed receptacle, and in the other they are borne upon a slender stem-like axis. The fig fruit is called a syconium. We thus have another illustration of the fact that the plan of the flower is more important in determining kinships than the appearance of the flowers or the plant (253).

SUGGESTIONS.—Compare the fig with the strawberry and raspberry; also with the burdock. All of these plants are very unlike the fig in morphology, but the contrast will bring out the differences and resemblances. Is the fig a receptacle in the sense in which that term is used with the mustard (166), or as it is used with the sunflower (201)?

LIX. PINES AND THEIR KIN

370. The pines are monœcious. Both kinds of flowers are in catkins. If one examines the Austrian or the Scotch pine just after growth has begun in the spring, he will find a cluster of light yellow pollen-bearing catkins at the base of the new growth, and a reddish fertile or seed-bearing catkin, or sometimes two of them (Fig. 321 *B*), on the tip of the shoot,—but not from a terminal bud,—and elevated two to six inches above the others.

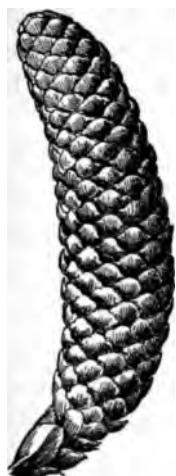


FIG. 320.

Staminate catkin
and scale of
pitch pine.



370a. This arrangement of the two kinds of flowers may suggest that of the hickory, in Fig. 160. The pupil should determine the relative numbers of sterile and fertile catkins, and should observe the profusion of pollen. Examine the common white pine, and others, to see if these relative positions of the two kinds of catkins obtain in all of them. Also examine the firs and spruces.

371. The pollen-bearing catkins soon fall. The scales, in most pines, are conspicuously widened at the outward end, and are attached to the axis by

a tapering base (Fig. 320, *a*). Beneath some of these scales are clusters of stamens which are wholly devoid of a perianth.

372. The fruit-bearing catkins persist, and become cones (or strobiles). Above each of the persistent cone-scales may be found two inverted ovules (*a c*, Fig. 321), wholly destitute of ovary. These ovules develop into winged seeds. The cone-scale is in the axil of a minute scale-like body.

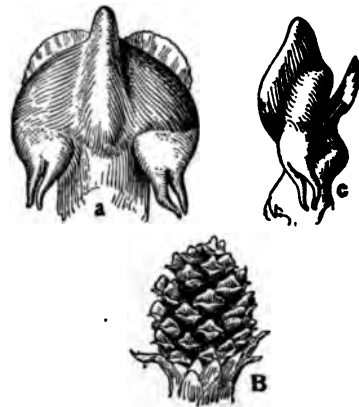


FIG. 321.

Details of young pistillate cone
of Austrian pine.

373. The pines, then, are radically unlike the other plants which we have studied, because they have no pericarps. The ovules are naked, and the pollen is therefore applied directly to the ovule. The flowers are also destitute of perianth.

374. The cones of pines arise on the growth of the season, but when they open and discharge the seeds, they are upon two-year-old wood. That is, the cones mature the second year. Is this true of the spruces and larches?

375. The cone does not necessarily open or discharge its seeds when it reaches maturity. The

pitch pine (Fig. 322), white pine, Scotch pine, and many others, open the second year; but the

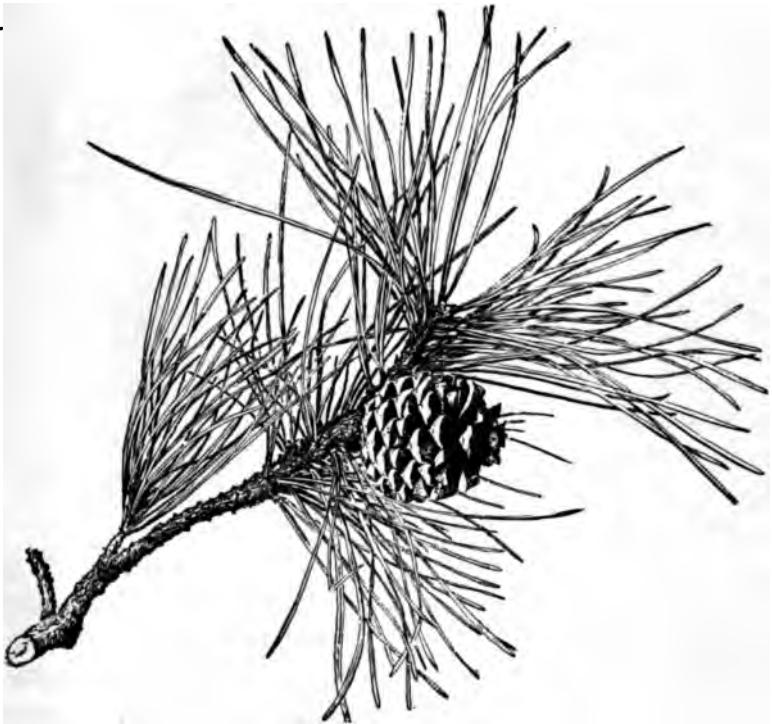


FIG. 322.

Foliage and cone of pitch pine.

Jack pine and others may not open for several years, and sometimes cones never open. Figs. 323 and 324 are cones of the Florida spruce pine. In the latter picture, the cone has persisted until it

has become imbedded in the wood of the branch, and it evidently cannot plant its seeds until the limb decays. It is a question if the seeds will then be viable.

375a. Do cones which, like Figs. 323 and 324, never open, contain good seeds, the same as other cones do? Let the pupil watch the effect of scorching by fire in opening cones.

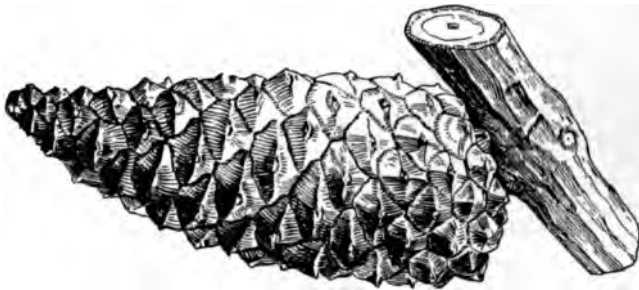


FIG. 323.

Cone of spruce pine.

376. We have now discerned two most important characters in plants,—the fact that some plants bear their ovules (and seeds) in a closed receptacle or ovary, whereas others bear naked seeds. These characters enable us to divide all flowering plants into two great classes, the angiosperms and the gymnosperms. The angiosperms, or those having a pericarp, comprise the greater part of our common plants, nearly all those, in fact, which we have studied up to this point. The gymnosperms,

bearing naked ovules, comprise the pines, spruces, firs, cedars, yews, junipers, cypresses, ginkgos, and the like.

376a. Far the larger part of flowering or seed-bearing plants (or the spermatophyta) are angiosperms. The gymnosperms are very



FIG. 324.

Cone overgrown by the branch.

old types, geologically considered. They comprise such plants as the pines, spruces (and all the Coniferae or cone-bearing plants), cedars, yews, cypresses and ginkgo,—the last cultivated as an ornamental tree from China and Japan. There are various fundamental differences between the angiosperms and the gymnosperms, but they are chiefly such as the pupil can understand only when he takes up the study of com-

parative anatomy and morphology; we cannot, therefore, give this type of plants adequate treatment in this book.

376b. Botanists are not agreed as to the morphology of the cone of the gymnosperms. Some consider that the ovule-scale represents an open carpel. Others think that this scale represents a placenta, and that the subtending bract is homologous with a carpel. Others accept neither view.

SUGGESTIONS.—The pupil knows that the lowermost and uppermost leaves and buds on any branch (not counting the terminal bud) are commonly smallest and apparently least efficient (42). Let him examine pine cones, to see in what part of the cone the most and best seeds are borne. He should also determine the position of the cones of the different pines and spruces: upon what part of the tree they are borne, how many together, and how long they persist.

LX. INFLUENCE OF POLLEN UPON THE FRUIT

377. We have found (147, 148) that fertilization by pollen is essential to the development of perfect seeds. One pollen grain is sufficient to impregnate an ovule; yet very many grains may fall upon a stigma, and the ovary may contain but a single ovule. The question is raised, therefore, as to what becomes of the extra or redundant pollen. We may suppose (from an analogy with buds) that many of the grains may fall out-right; and this is true. Does the pollen exercise any other function than to impregnate the ovule?

377a. The body or structure which is impregnated is, strictly speaking, not the ovule but the egg-cell of the embryo-sac; but an explanation of the process of fecundation is not intended here. The pollen grain sends out a tube (the process is generally called germination), which penetrates the stigma and style and reaches the embryo-sac. As a rule, one pollen grain fecundates one egg-cell, but the pollen-tube may branch and fecundate more than one egg-cell. There are certain instances in which seeds have been produced without fertilization, but they are exceptions, and do not require discussion here.

377b. In recent writings the embryo-sac is often denominated the macrospore, and its nucellus the macrosporangium. The pollen grain is called a microspore. These are terms of comparative morphology and physiology, and need not be used here.

378. We have seen that the pulp of the strawberry fails to develop at points where the akenes

fail (296). There are five styles and stigmas in the apple flower. If pollen is applied to two or three of them only, the corresponding carpels will develop and the remaining carpels will develop no seeds. The part of the apple in which the seeds are borne grows most rapidly and the apple becomes one-sided. If there are fewer pollen grains



FIG. 325.

One-sided tomato,
resulting from in-
sufficient pollen.

applied to the stigma of any flower than there are ovules in the ovary, the normal number of seeds may not form, and the fruit remains comparatively small. If it happens that the impregnated ovules are mostly upon one side of the ovary the fruit becomes one-sided, as in the tomato (Fig. 325). All this shows that the development of the seed exerts a great influence upon the development of the fruit; and since the development of the seed is dependent directly upon the pollen, it follows that the pollen supply is a most important factor in the production of large and symmetrical fruits.

379. Plants of very unlike kinds will not often inter-cross; yet it sometimes happens that after inter-pollination between such plants, the fruit will develop to considerable size, even though no seeds form. It is also found, by experiment, that the application of more pollen than is necessary for

complete impregnation often results in the production of extra large fruits. It is now believed, in other words, that pollen often exerts a secondary influence in stimulating the development of the pericarp.

379a. There is much discussion as to the "immediate influence of pollen," by which is meant the influence of the pollen in impressing the characteristics of its parent upon the identical fruit to which it is applied. In general, there seems to be no such influence, but there are well-determined exceptions.

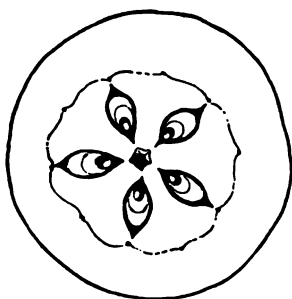


FIG. 326.

Non-pollinated apple.

380. If one were to examine the fruits which are dropped by any plant shortly after flowering-time, he would likely find many of them to be hollow or devoid of good seeds. This is readily observed in cultivated fruits, as apples and plums. Fig. 326 is a cross-section of such an apple, one-fourth larger than life. It turned yellow and fell. The aborted seeds indicate that it was not fertilized; and experiments give similar results. In other words, many ovaries will grow to considerable size without pollination, and then perish.

380a. Unfertilized plums sometimes reach a fourth their normal size before falling, especially those of the Wild Goose type. Persons who live in the extreme South should observe the cocoanuts.

(The specimens in Fig. 281 were probably not pollinated.) Observe any specimens of fruits which may be found upon the ground early in the season.

381. There are some fruits which may mature to normal size and appearance wholly without the aid of pollen, but they are seedless. Some of the hot-house cucumbers do this. Fig. 327 is an egg-plant fruit which has received no pollen, but which, although it persists upon the plant, refuses to grow to full size, as may be seen by the relative sizes of fruit and enlarging calyx. We may conclude by saying that impregnation is necessary to the development of seeds, that pollen may have a powerful secondary influence in developing the pericarp and fruit, that

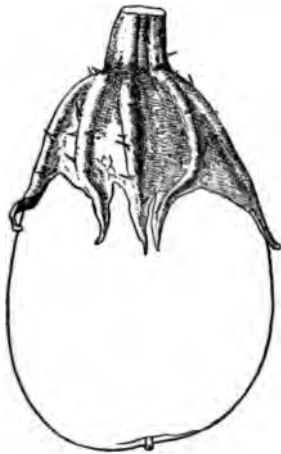


FIG. 327.

Non-pollinated egg-plant fruit.

very many ovaries enlarge for a time in the absence of pollination, and that some pericarps are known to develop normally wholly without the aid of either seeds or pollen.

381a. A somewhat full discussion of seedless forcing-house fruits and of the influence of pollen in developing size of fruit, may be found in Bailey's "Forcing-Book."

SUGGESTIONS.—These facts are most suggestive. The pupil will now want to cut every one-sided apple to see if its unsymmetry may be due to lack of pollination. When he is crossing plants (Obs. xlv.), he will want to experiment with much and little pollen and by putting pollen upon only a part of the stigmas. He will wonder whether one reason why cultivated apples grow so much larger than wild ones is because only one fruit commonly develops in each cluster (Fig. 46), and whether this is the one which chanced to receive the most pollen. He may even question if the reason why only one develops is because there is insufficient pollen for the fertilization and stimulation of more than one.

PART V

STUDIES OF THE PROPAGATION OF PLANTS

LXI. HOW A SQUASH PLANT GETS OUT OF THE SEED

382. The culmination of the activities of the plant is the propagation of itself. To this end the devious life-history, the mechanisms of the flowers, the varieties and peculiarities of the fruits, are subordinate. The supreme effort of the plant—if one may so speak—is its perpetuation. The most important vehicle of this perpetuation, in most higher plants, is the seed.

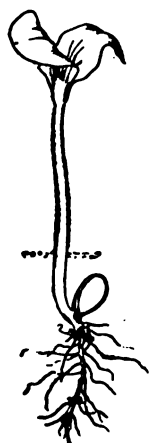


FIG. 328.
Squash plant
a week old.

383. If one were to plant seeds of a Hubbard or Boston Marrow squash in loose, warm earth in a pan or box, and were then to care for the parcel for a week or ten days,



FIG. 329.
Squash plant
which has
brought the
seed-coats
out of the
ground.

he would be rewarded by a colony of plants like that shown in Fig. 328. If he had not planted the seeds himself, or had not seen such plants before, he would not believe that these curious plants would ever grow into squash vines,

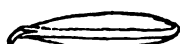


FIG. 330.
Germination just beginning.

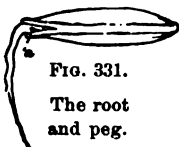


FIG. 331.
The root and peg.

so different are they from the vines which we know in the garden. This, itself, is a most interesting fact,—this wonderful difference between the first and the later stages of all plants, and it is only because we know it so well that we do not wonder at it.

384. It may happen, however, that one or two



FIG. 332.
Third day of root growth.

of the plants may look like that shown in Fig.

329. Here the seed seems to have come up on top of the plant,

and one is reminded of the curious way in which beans come up on the stalk of the young plant.

We are desirous to know why one of these squash plants brings its seed up out of the ground while all the others do not. We shall ask the plant. We may first pull up the two plants. The first one (Fig. 328) will be seen to have the seed-coats

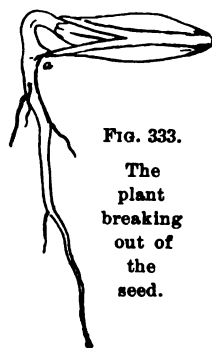


FIG. 333.
The plant breaking out of the seed.

still attached to the very lowest part of the stalk, below the soil, but the other plant has no seed at that point.

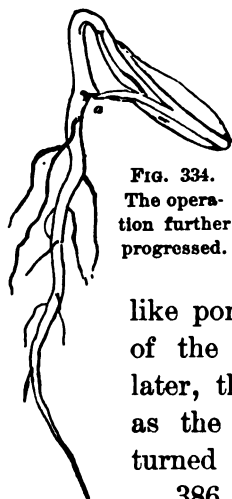


FIG. 334.
The operation further progressed.

385. We will now plant more seeds—a dozen or more of them—so that we shall have enough for examination two or three times a day for several days. A day or two after the seeds are planted, we shall find a little point or root-

like portion breaking out of the sharp end of the seed, as shown in Fig. 330. A day later, this portion has grown to be as long as the seed itself (Fig. 331), and it has turned directly downward into the soil.

386. There is another most curious thing about this germinating seed. Just where the root is breaking out of the seed (shown at *a* in Fig. 331), there is a little peg or projection. In Fig. 332, about a day later, the root has grown still longer, and this peg seems to be forcing the seed-coats apart. In Fig. 333, however, it will be seen that the seed-coats are really being forced apart by the stem or stalk above the peg, for this stem is now growing longer. The lower lobe of the seed has attached to the peg (seen at *a*, Fig. 333), and the



FIG. 335.
The plant just coming up.

HOW A SQUASH PLANT GETS OUT OF THE SEED 319

seed-leaves are backing out of the seed. Fig. 334 shows the seed a day later. The root has now produced many branches, and has thoroughly established itself in the soil. The top is also growing rapidly, and is still backing out of the seed, and the seed-coats are still firmly held by the obstinate peg.



FIG. 336.

The plant liberated from the seed-coats.

387. In the meantime, the plantlets which we have not disturbed have been coming through the soil. If we were to see the plant in Fig. 334 as it was "coming up," it would look like Fig. 335. It is tugging away trying to get its head out of the bonnet which is pegged down underneath the soil. In Fig. 336 it has escaped from its trap. It must now straighten itself up, as it is doing in Fig. 337, and it is soon standing stiff and straight, as in Fig. 328. We now see that the reason why the seed came up on the plantlet in Fig. 329, is because in some way the peg did not hold the seed-coats down (see Fig. 340), and the expanding leaves are pinched together, and they must get themselves loose as best they can.



FIG. 337.

The plant straightening up.

388. There is another thing about this squash plant which we must not fail to notice, and this

is the fact that these first two leaves came out of the seed, and did not grow out of the plantlet itself. We must notice, too, that these leaves are much smaller when they are first drawn out of the seed than they are when the plantlet has straightened itself up. That is, these leaves increase in size after they reach the light and air.

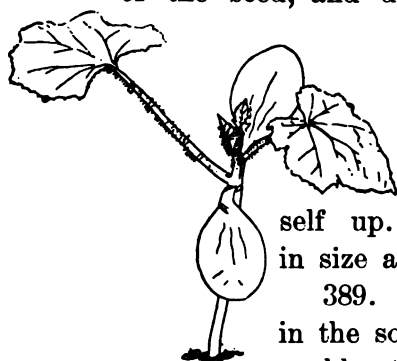


FIG. 338.

The true
leaves develop-
ing.

389. The roots are now established in the soil, and are taking in food which enables the plantlet to grow. The next leaves which appear (Fig. 338) are very different from these first or seed leaves.

They grow out of the little plant itself.

The picture shows these true leaves as they appear on a young Crookneck squash plant, and the plant now begins to look much like a squash vine.

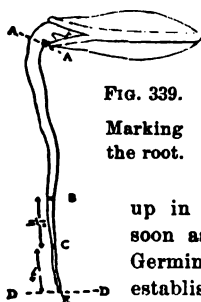


FIG. 339.

Marking
the root.

389a. The leaves which are borne in the seed are the cotyledons or seed-leaves. Their enlargement, after sprouting, is largely or wholly at the expense of the nutriment which is stored up in the seed. The true leaves (Fig. 338) appear as soon as the plantlet begins to gather materials for itself. Germination is not complete until the plantlet has thoroughly established itself in the soil, and the true leaves have begun to appear. The plantlet then becomes a plant.

The earlier part of the germinating process may be called sprouting.

389b. The incipient shoot which gives rise to the growth

HOW A SQUASH PLANT GETS OUT OF THE SEED 321

above the cotyledons (and which, as we shall see, is present in the seed) is the plumule. The plumule is really a bud.

390. We are now curious to know how the stem grows when it backs out of the seed and pulls the little seed-leaves with it, and how the root grows downwards into the soil. Pull up another seed when it has sent a single root about two inches deep into the earth. Wash it very carefully and lay it upon a piece of paper. Then lay a rule alongside of it, and make an ink mark one-quarter of an inch, or less, from the tip, and two or three other marks at equal distances above (Fig. 339). Now carefully replant the seed. Two days later, dig it up; we shall most likely find a condition something like that in Fig. 340. It will be seen

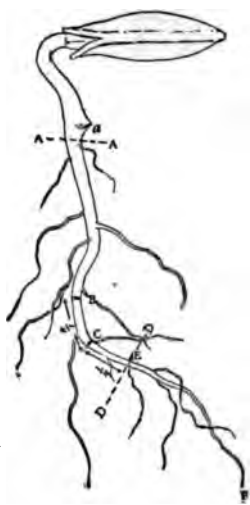


FIG. 340.

The root grows in the end portion.

that the marks E, C, B, are practically the same distance apart as before, and they are also the same distance from the peg, A A. The point of the root is no longer at D D, however, but has moved on to F. The root, therefore, has grown almost wholly in the end portion.

390a. Common ink will not answer for this purpose because it "runs" when the root is wet, but indelible ink, used for marking linen or for drawing, should be used. It should also be said that the roots of the common pumpkin and of the summer bush squashes are too fibrous and branchy for this test.

390b. It should be stated that the root does not grow at its very tip, but chiefly in a narrow zone just back of the tip; but the determination of this point is rather too difficult for the beginner, and, moreover, it is foreign to the purpose of this lesson.

391. Now let us make a similar experiment with the stem or stalk. Mark a young stem, as

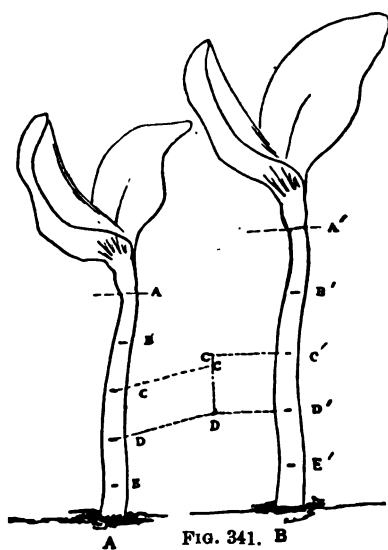


FIG. 341. B

The marking of the stem and the spreading apart of the marks.

at A in Fig. 341; but the next day we shall find that these marks are farther apart than when we made them (B, Fig. 341). The marks have all raised themselves above the ground as the plant has grown. The stem, therefore, has grown throughout its length rather than from the end. The stem usually grows most rapidly, at any given time, in the upper or younger portion; but the part soon reaches the limit of its growth and becomes sta-

tionary, and the growth continues beyond it. (See "Suggestions," p. 48.)

392. All this behavior of the germinating squash results in raising the foliage above the soil and in keeping the seed-coats beneath it. But suppose that the seed is not buried, but lies on the surface of the moist earth or is covered only with loose leaves or litter: then what happens? Fill a pot or box with earth up to half an inch below the rim, lay fresh squash seeds upon it, cover the pot with cardboard, and keep the seeds moist and warm. Watch the result.

SUGGESTIONS.—This experiment of germinating seeds upon the surface is always an interesting one. Peas germinate in this way very readily. Whenever this experiment is tried, other seeds of the same kind should be planted in the normal way, for comparative study.

LXII. GERMINATION OF THE ONION

393. A sprouting onion seed is seen in Fig. 342. The process further developed is shown in Fig. 343. The root is elongating from the point *a*, and a stem-like part is growing above that point and is pushing the seed upward towards the surface of the ground.

394. The loop which is beginning to form in Fig. 343 has greatly developed in Fig. 344, and the tip of it has reached the surface of the ground. In other words,



FIG. 342.
Sprouting onion seed.

the plantlet is "coming up." This loop soon becomes conspicuous, as in Fig. 345. The gardener is now able "to see the row," and tillage is begun.

395. The loop elongates, but the tip of it is held firmly in the soil, and the whip-lash performance, shown in Fig. 346, is the result. The lash finally breaks loose, and the plantlet straightens up, as in Fig. 347. If the plant is watched for a few days, the observer will discover that the subsequent growth does not take place from the large part, *d*, but from a new member, *e*, which arises from a chink in the base of the plantlet (near *a* in Figs. 343, 344). The



FIG. 343.

Sprouting
onion seed.



FIG. 344.

The loop
breaking
through the
ground.

loop is not a stem, fact, a cotyledon; the seed-coats are of the ground, and days on the tip of part, *e*, then is



FIG. 345.

The onion
"coming up."

therefore. It is, in and in mellow soil usually pulled out are held for some the cotyledon. The the plumule.

395a. There are sev-
nation of the onion, some
the engravings, which the pupil should discover and interpret for himself. At what point, for example, are the seed-coats attached?

eral points in the germi-
of which are suggested in

And where is the slit from which the plumule emerges? Onion seeds germinate slowly, but the process may be hastened by soaking them in warm water for a few hours. Be sure that the seeds are fresh. Perhaps the pupil can have access to an onion patch in very early spring. In a warm room and with fresh seeds, the entire process of germination may be completed in two weeks.

396. In the squash we found two cotyledons, but in the onion there is only one. This fact is of great significance, because it affords a natural character for the classification of plants. We have already (376) divided all flower-bearing plants into two categories, the angiospermæ, with distinct ovary, and the gymnospermæ, without distinct ovary. We may again divide the angiosperms into two classes or groups,—the dicotyledons (two seed-leaves) and the monocotyledons (one seed-leaf).

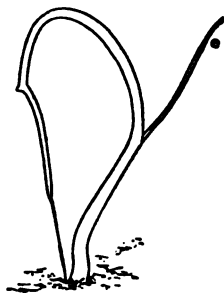


FIG. 346.
The whip-lash.

397. These characters derived from the number of cotyledons, are not mere arbitrary or conventional standards for the classification of plants, but they are correlated with other features. For example, the dicotyledonous plants are more or less clearly characterized by making their increase in diameter of stem by means of rings or layers of growth upon the outside of the woody cylinder and underneath the bark; they are, therefore, sometimes called exogens ("outside growers"). They

often have a distinct central pith, which sometimes disappears, leaving the stem hollow. The parts of the flowers are most commonly in fives or fours, and the leaves are, for the most part, distinctly netted-veined.



FIG. 347.

Germination completed.

397a. Dicotyledonous plants comprise all the trees of northern countries, and such tribes as the mustards, legumes, roses, composites, cacti, pigweeds, honeysuckles, and the orchard fruits of the North. In some cases there are more than two cotyledons.

398. The monocotyledonous plants, on the other hand, increase in diameter by means of new woody bundles scattered in the stem, and there may be no distinct and separable bark, as there is in the dicotyledons; they are, therefore, sometimes called endogens ("inside growers"). The flowers are built mostly upon the plan of three (220a), and the main veins of the leaves are generally essentially parallel to each other (but the secondary veins are usually interwoven or netted). As a rule, the leaves do not fall away with a clean scar, as they do in the dicotyledons, a point which we have already discovered (39a).

398a. Monocotyledonous plants are less numerous, as to kinds, than the dicotyledons. Here belong all the palms, lilies, grasses and cereal grains, rushes, sedges, orchids, cannas, bananas, arums and duckmeats. Most bulbous plants are monocotyledons. Some of these plants are illustrated in Figs. 39, 40, 41, 58, 74, 101, 102, 119, 138, 142, 148, 165, 166, 167, 168, 183, 184, 188, 189, 196, 199, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 254, 281.

LXIII. GERMINATION OF BEANS

399. Plant a few common beans and watch the germination. The plantlets back out of the soil much as the squash does, and the cotyledons, *a*, Fig. 348, are elevated into the air. These cotyledons remain practically the same size as they were in the seed, however, and do not become conspicuously green and leaf-like.



FIG. 348.
Germination of
common bean.



FIG. 349.
Germination of
Scarlet Runner bean.

White Dutch Runner bean. The first foliar parts to appear are true leaves (Fig. 349), and if the

400. At the same time, plant seeds of the Scarlet Runner or

plant be dug up, the cotyledons will be found to have remained under the ground. Observe carefully at what point the roots start out from the seed.

401. There are, then, two types of germination as respects the position of the cotyledons. In one type, the seed-leaves rise above ground, or the germination is epigeal ("above the earth"); in the other, they remain where the seed was planted, or the germination is hypogeal ("below the earth").

401a. The pupil should make a careful comparison of the differences in germination between the two types of beans mentioned above. He may profitably add a third factor to the experiment by including the garden pea. If he has access to oak trees, he may watch the germination of the acorns as they lie upon the ground in very early spring. Examine horse-chestnuts.

402. Measure the beans before they are planted, taking the length, width and thickness. If delicate balances or scales are at hand, it may be well to weigh them, also. Then observe the increase in size of the beans. Is this swelling associated with heat or moisture, or both? The pupil can answer this question by planting some seeds in dry, warm earth and others in moist, cool earth (which is kept little above freezing), and by otherwise varying the experiment. Do dead seeds—those which are very old or which have been baked—swell when planted? The pupil will find

that the swelling of the seed is the first obvious stage in germination.

403. Plant beans in moist cotton or sawdust, or lay them in folds of heavy, damp cloth. How far will the sprouting progress? Will the first true leaves develop? In other words, for how long can the plantlet grow upon the nutriment which is stored in the seed?

404. When the true leaves have begun to develop (as in Figs. 348 and 349), carefully lift the plant, with the soil which is attached, and then, in a basin, wash away the earth until the roots are white and clean. Then, by the aid of a lens or by holding the roots to the light, see the covering of very fine hairs upon the roots. It is these little organs which hold most of the earth on the roots when the plant is carefully pulled up. They are the root-hairs, and they are active agents in absorbing food.

404a. Several profitable lessons may be made in the study of the root-hairs of whatever seedling plants may be at hand in gardens or elsewhere. How soon after germination do they appear? Do they persist as the root becomes old, or are they shed upon the older parts? Do full-grown or large plants have root-hairs? Look for them on the very youngest parts of the roots. When seeds are germinated as recommended in 392 and 403, the root-hairs are much more readily seen.

405. We know that roots go downwards and stems go upwards. How soon is this difference

manifested in the germinating bean? Do the two parts take these opposite directions even when the beans germinate in a dark place? We shall find that there is an inherent, or inborn, tendency for the root to grow down and the stem to grow up.

405a. The discussion of the physiological causes which have determined this differentiation between the root and stem is not germane to this book; although it may be said that gravitation plays an important part in the movements. For the purpose of designating some of these facts or phenomena, the words *geotropism* and *heliotropism* have been used,—the former designating movement into or towards the earth, and the latter movement towards the light.

SUGGESTIONS.—The pupil should make these tests with beans. He will find other interesting points, if he watches the process of germination closely. When some of the seeds have produced straight roots an inch or so long, remove them carefully and hang them with the root uppermost in a moist and warm atmosphere, as under a bell-jar or inverted glass bowl which is set in water. Observe how the roots tend to turn downwards and the plumule to turn upwards. Or, sprouting seeds may be placed in a horizontal position. It is interesting to observe how the root gets around stones and other hard objects in the soil. The roots of any plant which grows in very stony or hard, gravelly soil are good subjects for observation. Radishes are also interesting for germinating studies; and they show *heliotropism* quickly and emphatically when growing where the light all comes from one direction, as from a side window.

The beans may be planted in pans or boxes which are set in the windows of the school-room, although care should be taken that the soil does not become too dry if it is exposed directly to the sun. The handframes mentioned in Obs. lxxiii. will be found to be useful with which to make germination studies. The pupil usually takes more interest in the experiments, however, if he has them constantly under his eye. Perhaps each pupil can be pro-

vided with a small flower-pot, or other dish, or even with a cigar-box, and be allowed to have it upon his desk. If the elongation of the parts is to be watched very closely, and especially if the root is to be marked in order to observe its method of growth (390, 390a), the seeds may be germinated between damp blotting papers. If a dozen or more seeds are started, a record may be kept of the various stages in germination by pressing the plants, as well as by drawing them.

LXIV. WHAT IS A SEED?

406. The two most important characteristics of seeds we have already learned,—the facts that they are the result of the fertilization of the ovule by a pollen-grain (377a), and that they contain a miniature plant. This condensed and miniature plant in the seed is called the embryo. The phenomena of fertilization are too obscure to be clearly understood, much less to be seen, by the beginner; but it may be said that the nucleus of the pollen-grain unites with the nucleus of the egg-cell in the embryo-sac, and the result of this union is the embryo.



FIG. 350.

The parts of a bean seed.

407. Let us return to the bean. In the pod (Fig. 248), the beans are seen to be attached by short stalks to the edge of each valve. The

stalk is called, in all seeds, the funiculus. When the funiculus breaks away from the seed, it leaves a scar (D, Fig. 350). This scar is the hilum.

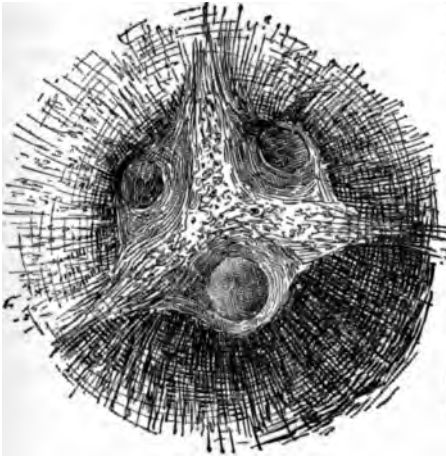


FIG. 351.

Micropylar scars of cocoa-nut.

408. If we split the bean lengthwise (preferably after it has been soaked in water for a few hours), we find that the seed is composed of two thick cotyledons; and these are the parts which are afterwards elevated

into the air (*a*, Fig. 348). One-half of a bean (that is, one cotyledon) is shown in Fig. 350. The other cotyledon was attached at C. The plumule is at S, and the incipient stem, or caulicle, at O. All these parts—cotyledons, caulicle, plumule,—constitute the embryo.

408a. Over the point of the caulicle, the close observer will find a minute depression and a hole leading into the bean. This is the micropyle, and is the point at which the pollen-tube entered, and the place through which the root breaks in germination. In the cocoa-nut the positions of the three micropyles are shown by the scars (Fig. 351) but since only one of the locules develops a seed (332a), germination takes place through only one scar.

409. We are now curious to know if there is anything in the structure of the embryos to suggest the different behaviors of the two beans in Figs. 348 and 349. Fig. 352 shows the cotyledons of a common bean laid open; and Fig. 353 is a similar picture of the Scarlet Runner bean. The node, or place of attachment of the cotyledons, is at C (one cotyledon, of course, having been broken away). The

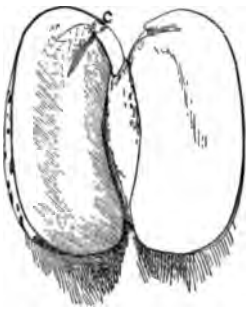


FIG. 352.

Parts of common bean.

caulicles are the parts pointing downwards, and the two leaves of the plumule lie at the left. The observer will see that the space between C and the plumule is very different in the two beans. These different lengths are suggestive of what takes place in germination,—the greatest elongation of the stem in the common bean takes place beneath the cotyledons, whereas the greatest elongation in the Scarlet Runner takes place above the cotyledons: in one case the caulicle elongates, in the other it does not.

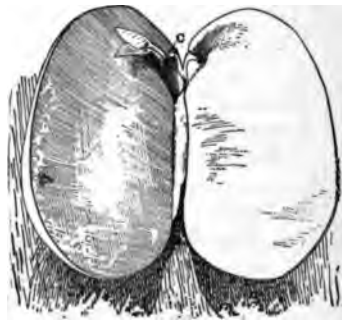


FIG. 353.

Parts of Scarlet Runner bean.

409a. The internode lying above the point of attachment of the cotyledons—between the cotyledons and the plumule—is called the epicotyl; that below the cotyledons is the hypocotyl. The hypocotyl was formerly called the radicle, upon the supposition that it is an incipient root; but it is a stem (except, perhaps, the very tip), and the root develops from its end.

410. The embryos of the squash and bean occupy the whole interior of the seed, and the nutriment which sustains the sprouting plantlet is stored in the cotyledons. In the onion it is not so. Fig. 354 is a section of an onion seed. The monocotyledonous embryo is coiled up in a mass of starchy matter; and a similar condition is seen in the buckwheat (Fig. 355). Nutritive material stored outside the embryo is called the endosperm.



FIG. 354.
Section of
onion seed.



FIG. 355.
Section of
buckwheat
seed.

410a. The endosperm varies greatly in quantity and in physical and chemical character. In many plants, as the cereal grains, it affords most of the material which is utilized for human food. In the cocoa-nut only a part of the liquid matter solidifies into endosperm, leaving the "milk" in the center; the embryo is comparatively very small, and can be found, of course, near the micropyle.

411. A seed, then, is a body which is the direct product of a flower and a result of a sexual process, and which contains a miniature plant or embryo; and its office is to produce a new plant. In nearly all cases the embryo is

enclosed in seed-coats, and it is often imbedded in endosperm.

SUGGESTIONS.—Only the most obvious parts and features of seeds have been mentioned here, but these characters are sufficient to enable the pupil to make profitable comparisons between any seeds which may come to his hand. It is good practice to set beginners searching for the cotyledons in large seeds. Where, for example, are the cotyledons in the pecan (Fig. 356), acorn, maize,

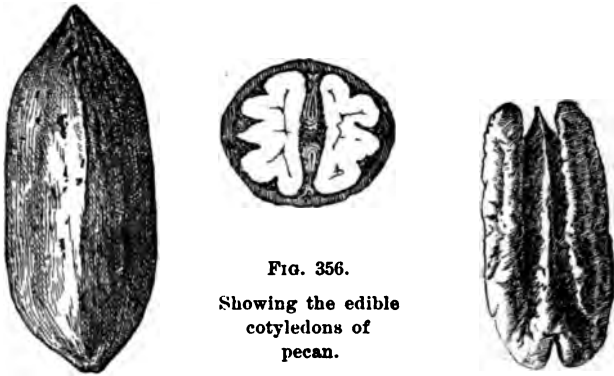


FIG. 356.
Showing the edible
cotyledons of
pecan.

wheat, castor bean, sweet pea, apple, peach, morning-glory, garden balsam, cucumber, orange, canna, cocoa-nut, and other large seeds? The parts can generally be made out more easily if the seeds are soaked in tepid water for a few hours. It is more important, however, if facilities are at hand, to set the pupil to the study of the behavior of seeds and plantlets in germination. An interesting series of studies can be made from a comparison of the form of the cotyledons with that of the first true leaves, and of the gradation from the character of the first leaves to those which are characteristic of the mature plant. Are there differences in cotyledons and first leaves between the different horticultural varieties of the same plant, as between the different kinds of tomatoes and

red peppers? There is a wealth of information respecting germination in the two thick volumes of Sir John Lubbock's "Contribution to Our Knowledge of Seedlings."

LXV. THE DISPERSION OF SEEDS

412. It must be an advantage to any kind of plant if its seeds are widely dispersed, thereby affording it more chances to find a place in which to live and thrive. The earth is now covered with plants, and there is, therefore, great competition, or struggle for existence. Only a few seeds can produce mature plants, for the earth could not contain the possible offspring of all plants. Even one kind of plant, if allowed to multiply to its full capacity, would soon cover the earth. (See Obs. lxxiv.)

413. Most seeds fall and remain near the parent plant, and the colony of parents and offspring tends gradually to enlarge. In plants which mature very slowly, however, as the forest trees, and which are, therefore, exposed for a long time to the struggle for existence, the colony is likely to become broken and scattered, so that the trees occur singly here and there; but under certain conditions, the colony may dominate the area, and a continuous and homogeneous forest is the result. The seeds of the greater number of plants merely drop

to the ground when the fruits are ripe, and have no special means of becoming widely disseminated.

414. There are certain structures and appendages of seeds and fruits, however, which favor their dispersion. The most numerous types are those which are carried by the wind. The thistle-down and dandelion-balloons are familiar and perfect examples of wind-disseminated seeds. The key-fruits (Obs. li.), and all the tribes of winged seeds, are scattered by winds.

415. In some cases entire plants, or large parts of them, are carried long distances by the wind, dropping their seeds by the way. A perfect example of this mode of dissemination is the Russian thistle, which is now invading great areas in the West. The plant is easily detached from the earth in the fall, and the dense, globular top—often larger than a bushel basket—is caught up by the winds and rolled mile after mile across the prairie.

415a. The various "tumble-weeds" are dispersed in the same way, of which familiar examples are the hair-grass (*Panicum capillare*), white pigweed (*Amarantus albus*), and the cyclone plant or cycloloma of the West.

416. Many seeds are carried upon the coats or feet of animals. The farmer knows how full of seeds and "stick-tights" the sheeps' fleeces are if the animals run in wild or weedy pastures. Many strange plants spring up near carding factories,

where wool is cleaned. All the types of hooks and spines fit the seed or fruit to be carried by animals, or even upon garments of men. The reader will recall the sand-bur, clot-bur, burdock, pitchforks, beggar's-ticks, and the like. Some sticky seeds, as those of the mistletoe, are carried on the feet of birds; and the mud upon the hoofs of horses and cows and the feet of birds often contains seeds of various plants.

417. The seeds of fleshy fruits are usually bony, and although the fruits are eaten by birds, or even by mammals, the seeds may not be injured. Cherries, raspberries, blackberries, juneberries, are widely spread in this manner by birds. In like way, oats, maize and grasses may be disseminated by herbivorous animals. One will often find such plants springing up in woods along horse-trails.

418. Many plants become the companions of cultivated plants because their seeds cannot be separated readily by the machines used for cleaning seed. Thus the cockle (Figs. 143, 275, 276) lives with the wheat because its seeds are about the same diameter as the wheat seeds, and pass through the screens; and the plant also has habits similar to those of the wheat, whereby it is able to live under the same conditions. Many weeds of lawns and meadows are plants whose seeds cannot be separated easily from the grass seeds.

419. Some seeds may be carried long distances by water. If wild rice is sown near the source of a stream, it will gradually work down stream, partly, perhaps, through the agency of birds, but more directly by means of the water. The "sea-beans" which are often so plenty on certain coasts of Florida are leguminous seeds carried up from the West Indies by ocean currents. The cocoa-nut is the example most commonly cited of dispersion by water. Its buoyancy and impervious husk fit it to be carried very long distances on the sea.

420. A few plants have explosive fruits, by means of which the seeds are dispersed for a short distance. We have already seen some of them (316, 316*a*, 316*b*, 331).

421. The seeds of some plants germinate irregularly, part of them coming up the first year and others, from the same tree, not until the second or third year. Many hard and bony seeds, like those of the haws and hawthorns, are of this category. By extending the germination over two or three years, the plant may have more chances of finding a condition in which it can thrive.

422. The dispersion of plants depends, therefore, upon two sets of factors: the structure of the seed itself, which allows it to be disseminated by wind or other means; and the physical conditions

or environments, which determine whether the seed can germinate and the plant thrive after dissemination has taken place. The pupil can readily observe how important the factor of environment is by noticing how readily weeds spring up along roadsides, railways, lake shores, and in newly cleared land. If the pupil is fortunate enough to know of a meadow which has been plowed and the land then neglected, let him watch what takes place; or, he may consider why it is that weeds spread more rapidly in gardens than in meadows.

423. While there are evident means by which the seeds of plants are disseminated, as we have now indicated, the pupil must nevertheless be warned that it is easy to overstate the importance of such features. There is too great tendency to endeavor to find a specific use or adaptation for every attribute or structure of a plant, and then to explain its origin by supposing that it came about in order to fulfil such an adaptation. But we really cannot understand plants by interpreting them solely upon their present or obvious characters: the reasons for the appearing of given attributes should be sought in the genealogy, not in the present-time characteristics. It is possible that many of these structures which seem to us to have arisen for the purpose of dispersing the seeds may have originated as incidental or cor-

relative structures, and that it merely so happens that they serve a special but incidental purpose in disseminating the plant. If we once assume that every feature of a plant is adapted to some specific purpose, and that it has arisen by means of the effort of the plant to adapt itself to such purpose, we are apt to find adaptations where there are none. We are really throwing our own thoughts and feelings into the phenomena; and we are developing a superficial method of looking at nature. (Compare 338, 339.)

423a. The word adaptation is used technically, in evolution writings, to designate the fitness of an organism, or any part of an organism, to perform certain functions or to live in certain environments. Thus, a flower is adapted to cross-pollination, or a plant to dry soil, or to a cold climate. Adaptive modifications are such as obviously prepare the organism to live in given environments.

423b. Correlative or correlated characters are concomitants of the main or type characters. They are incidental features, which have been carried along by the main line of ascent, and which are of little significance to the present well-being of the organism.

423c. The genealogy of an organism is called its phylogeny. The life-history of a single or individual organism is its ontogeny. That is, phylogeny is the natural history of the race, whereas ontogeny is the natural history of a single individual. Phylogenetic characters, therefore, are those which have come down from the ancestry; ontogenetic characters are those which have originated within the life-time of a given individual.

423d. An acquired character is an ontogenetic character which is obviously the result of some environmental circumstance, as of soil, light, or temperature.

SUGGESTION.—Let the teacher assign one kind of plant to each pupil, asking him to discover how the seeds are dispersed.

LXVI FERNS

424. Maidenhair ferns are frequent in woods, and are common in cultivation. The leaves of



FIG. 357.

Fruiting pinnules of maiden-
hair fern.

large or mature plants often have a stiffish and angular look, and if such leaves are examined it will be found that the edges are turned under (as in Fig. 357). If these flaps are raised, many minute brownish bodies will be discovered, adhering to their surface. These bodies, which are called sporangia

or spore-cases, contain numerous spores, which are barely visible to the naked eye; and these spores germinate and produce new plants.

424a. The leaf-blade of a fern is known as a frond, a term which is also applied to the leaf-like bodies of duckmeats (252) and to the leaf-like parts of certain other plants, where there is little distinction of ribs or veins and no well-differentiated blade. The stem of the frond is called a stipe.

425. A bit of an aspidium, one of the common pinnate ferns of woods, is shown in Fig. 358. Four lobes of the frond are drawn, showing a row of dots upon either margin. One of these

dots is enlarged at *t*. It is made up of a shield-shaped scale covering a colony of sporangia. One of the sporangia is much enlarged at *e*, and it contains many spores. The dot *t* is known as a fruit-dot or sorus (plural sori), and the shield-like scale is an indusium. In the maidenhair, the sori are marginal, and the reflexed edge of the frond forms the indusium.

426. The so-called sensitive fern, which is very common in low grounds, is illustrated in Fig. 359. At the right is a leafy or sterile frond, and at *A* a fertile frond. This fertile frond has the same fundamental plan or structure as the other one has, but the edges of the lobes or divisions are rolled backwards and form a covering for the indusia and sori. Here, then, are three general types of fruit-bearing,—those in which the edge of the frond serves as indusium, those having a scale-like indusium, and those having a scale-like indusium but the sori covered by the revolute margins of the contracted frond. In many ferns the sori are naked; that is, there are no indusia. There are other types, but they need not be discussed here. The best way to see the spores of ferns is to press a ripe fruiting



FIG. 358.

Fructification of a shield-fern.

frond between sheets of white paper. When the frond is perfectly dry, the spores will be found as a dust-like covering upon the paper.

426a. The primary complete divisions of a frond are called pinnae, no matter whether the frond is pinnate or not. In ferns the word pinna is used in essentially the same way that leaflet is



FIG. 359.

Fronds of the sensitive fern.



FIG. 360.

Diagram to explain the terminology of the frond.

in the once-compound leaves of other plants. The secondary leaflets are called pinnules, and in thrice, or more, compound fronds the last complete parts or leaflets are ultimate pinnules. The diagram (Fig. 360) will aid in making the subject clear. If the frond were not divided to the midrib, it would be simple, but this diagram represents a compound frond. The general outline of the frond, as bounded by the dotted line, is ovate. The stipe is very short.

The midrib of a compound frond is known as the rachis. In a decompound frond, this main rachis is called the primary rachis.

Segments (not divided to the rachis) are seen at the tip, and down to *h* on one side and to *m* on the other. Pinnæ are shown at *i*, *k*, *l*, *o*, *n*. The pinna *o* is entire; *n* is crenate-dentate; *i* is sinuate or wavy, with an auricle at the base; *k* and *l* are compound. The pinna *k* has twelve entire pinnules. (Is there ever an even number of pinnules on any pinna?) Pinna *l* has nine compound pinnules, each bearing several entire ultimate pinnules.

Four pinnæ of the common wild maidenhair fern are shown in Fig. 358; but is the maidenhair frond pinnate?

427. We have now seen that the spores, or "seeds,"



FIG. 361.
Scouring-
rush.



FIG. 362.
Ground-pine, a
club-moss.



FIG. 363.
A lycopodium with
sporangia in the axils of
the *stipe* leaves

of ferns are borne upon the leaves, and that they are not preceded by flowers. The ferns are members of that numerous class known as flowerless plants or cryptogams. We have thus far studied the flowering plants or phanerogams.



FIG 364.

A true moss, natural size.

428. Although the spore performs the office of "seed" in propagating the plant, it is structurally very unlike a seed. It is not the product of a sexual process, and it contains no embryo. It is a comparatively simple cellular body (very often only a single cell), and is commonly much more minute than any seed. Its formation and germination, therefore, are not comparable with those processes in the seed, and since the beginner cannot see the phenomena for himself, it is useless to describe them here.

428a. The ferns and their allies comprise the class known as pteridophytes or vascular cryptogams, which are green and leaf-bearing flowerless plants having woody bundles or fiber, and vessels, in their stems. Aside from the ferns, the class includes the equisetums or scouring-rushes (Fig. 361), club-mosses (but not the true mosses) and selaginellas. There are nearly three thousand kinds of ferns known. Those who desire to pursue the subject should begin with Underwood's little book, "Our Native Ferns and their Allies," or Dodge's "Ferns and Fern Allies of New England." Persons who desire to study the subject in detail should also have

Eaton's "Ferns of North America," in two quarto volumes, with colored plates. If it is desired to cultivate ferns, Robinson's "Ferns in Their Homes and Ours" should be consulted.

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SUGGESTIONS.—The teacher may interest the pupils by asking them, upon a certain day, to collect one specimen of each of the kinds of ferns of a given neighborhood. The fronds of some kinds hold their form and color all winter, even under the snow. In fact, ferns are among the treasures of winter woods. In the spring, young people are always interested in the uncoiling heads of ferns (Fig. 61). The shaggy stipes and hard, strong rootstocks are worth attention.

LXVII. MUSHROOMS AND THEIR KIND

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430. If younger plants are examined (Fig. 366),

it is seen that the pileus is more nearly spherical, and in very young ones, as *b*, Fig. 365, the annulus is not present. The margin of the pileus is tied to the stipe by a very thin and delicate veil, and as the pileus expands this veil is ruptured, a part of it persisting as a ragged fringe



FIG. 365.

Cultivated mushroom.



FIG. 366.

Clump of mushrooms.

(observe the margin of the large cap in Fig. 365) on the edge of the pileus and the remainder forming the annulus upon the stipe.

431. Upon the under side of the pileus (Fig. 365) are numerous hanging flaps or gills. Let the pupil determine if these gills, or lamellæ, are all of equal length, and if they are joined to the stipe. He should also observe the color of the gills, and determine if it changes with the age of the plant. Now let the pupil secure a pileus of

a full-grown and fresh mushroom, cut off the stipe even with the lower edges of the gills, and then lay the cap, bottom down, on a piece of white paper in a dry room, and cover it with a bowl or bell-jar to protect it from currents of air. In a few hours, or a day, carefully lift the cap. The pupil will find a copious deposit of "dust," in the form of a reverse pattern of the gills. This dust is made up of spores: and such a diagram is called a "spore-print." We conclude, then, that the gills are fruiting bodies, bearing spores in countless numbers.

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432a. The tissue of this underground mycelium is not different in kind from that of the stipe and pileus, and the botanist calls all the vegetative tissue of the mushroom mycelium. The pupil may be fortunate enough, in digging up mushrooms, to find little knobs or "buttons" on the underground mycelium, showing the mushrooms in their young state.

432b. In popular usage, the word mushroom is applied to the fleshy and soft plants of this class, and toadstool to the very thin

or environments, which determine whether the seed can germinate and the plant thrive after dissemination has taken place. The pupil can readily observe how important the factor of environment is by noticing how readily weeds spring up along roadsides, railways, lake shores, and in newly cleared land. If the pupil is fortunate enough to know of a meadow which has been plowed and the land then neglected, let him watch what takes place; or, he may consider why it is that weeds spread more rapidly in gardens than in meadows.

423. While there are evident means by which the seeds of plants are disseminated, as we have now indicated, the pupil must nevertheless be warned that it is easy to overstate the importance of such features. There is too great tendency to endeavor to find a specific use or adaptation for every attribute or structure of a plant, and then to explain its origin by supposing that it came about in order to fulfil such an adaptation. But we really cannot understand plants by interpreting them solely upon their present or obvious characters: the reasons for the appearing of given attributes should be sought in the genealogy, not in the present-time characteristics. It is possible that many of these structures which seem to us to have arisen for the purpose of dispersing the seeds may have originated as incidental or cor-

relative structures, and that it merely so happens that they serve a special but incidental purpose in disseminating the plant. If we once assume that every feature of a plant is adapted to some specific purpose, and that it has arisen by means of the effort of the plant to adapt itself to such purpose, we are apt to find adaptations where there are none. We are really throwing our own thoughts and feelings into the phenomena; and we are developing a superficial method of looking at nature. (Compare 338, 339.)

423a. The word adaptation is used technically, in evolution writings, to designate the fitness of an organism, or any part of an organism, to perform certain functions or to live in certain environments. Thus, a flower is adapted to cross-pollination, or a plant to dry soil, or to a cold climate. Adaptive modifications are such as obviously prepare the organism to live in given environments.

423b. Correlative or correlated characters are concomitants of the main or type characters. They are incidental features, which have been carried along by the main line of ascent, and which are of little significance to the present well-being of the organism.

423c. The genealogy of an organism is called its phylogeny. The life-history of a single or individual organism is its ontogeny. That is, phylogeny is the natural history of the race, whereas ontogeny is the natural history of a single individual. Phylogenetic characters, therefore, are those which have come down from the ancestry; ontogenetic characters are those which have originated within the life-time of a given individual.

423d. An acquired character is an ontogenetic character which is obviously the result of some environmental circumstance, as of soil, light, or temperature.

SUGGESTION.—Let the teacher assign one kind of plant to each pupil, asking him to discover how the seeds are dispersed.

LXVI FERNS

424. Maidenhair ferns are frequent in woods, and are common in cultivation. The leaves of



FIG. 357.

Fruiting pinnules of maiden-
hair fern.

large or mature plants often have a stiffish and angular look, and if such leaves are examined it will be found that the edges are turned under (as in Fig. 357). If these flaps are raised, many minute brownish bodies will be discovered, adhering to their surface. These bodies, which are called sporangia

or spore-cases, contain numerous spores, which are barely visible to the naked eye; and these spores germinate and produce new plants.

424a. The leaf-blade of a fern is known as a frond, a term which is also applied to the leaf-like bodies of duckmeats (252) and to the leaf-like parts of certain other plants, where there is little distinction of ribs or veins and no well-differentiated blade. The stem of the frond is called a stipe.

425. A bit of an aspidium, one of the common pinnate ferns of woods, is shown in Fig. 358. Four lobes of the frond are drawn, showing a row of dots upon either margin. One of these

dots is enlarged at *t*. It is made up of a shield-shaped scale covering a colony of sporangia. One of the sporangia is much enlarged at *e*, and it contains many spores. The dot *t* is known as a fruit-dot or sorus (plural sori), and the shield-like scale is an indusium. In the maidenhair, the sori are marginal, and the reflexed edge of the frond forms the indusium.

426. The so-called sensitive fern, which is very common in low grounds, is illustrated in Fig. 359. At the right is a leafy or sterile frond, and at *A* a fertile frond. This fertile frond has the same fundamental plan or structure as the other one has, but the edges of the lobes or divisions are rolled backwards and form a covering for the indusia and sori. Here, then, are three general types of fruit-bearing,—those in which the edge of the frond serves as indusium, those having a scale-like indusium, and those having a scale-like indusium but the sori covered by the revolute margins of the contracted frond. In many ferns the sori are naked; that is, there are no indusia. There are other types, but they need not be discussed here. The best way to see the spores of ferns is to press a ripe fruiting



FIG. 358.

Fructification of a shield-fern.

frond between sheets of white paper. When the frond is perfectly dry, the spores will be found as a dust-like covering upon the paper.

426a. The primary complete divisions of a frond are called *pinnae*, no matter whether the frond is pinnate or not. In ferns the word *pinna* is used in essentially the same way that leaflet is



FIG. 359.

Fronds of the sensitive fern.



FIG. 360.

Diagram to explain the terminology of the frond.

in the once-compound leaves of other plants. The secondary leaflets are called *pinnules*, and in thrice, or more, compound fronds the last complete parts or leaflets are *ultimate pinnules*. The diagram (Fig. 360) will aid in making the subject clear. If the frond were not divided to the midrib, it would be simple, but this diagram represents a compound frond. The general outline of the frond, as bounded by the dotted line, is ovate. The stipe is very short.

The midrib of a compound frond is known as the rachis. In a decompound frond, this main rachis is called the primary rachis.

Segments (not divided to the rachis) are seen at the tip, and down to *h* on one side and to *m* on the other. Pinnæ are shown at *i*, *k*, *l*, *o*, *n*. The pinna *o* is entire; *n* is crenate-dentate; *i* is sinuate or wavy, with an auricle at the base; *k* and *l* are compound. The pinna *k* has twelve entire pinnules. (Is there ever an even number of pinnules on any pinna?) Pinna *l* has nine compound pinnules, each bearing several entire ultimate pinnules.

Four pinnæ of the common wild maidenhair fern are shown in Fig. 358; but is the maidenhair frond pinnate?

427. We have now seen that the spores, or "seeds,"



FIG. 361.
Scouring-
rush.



FIG. 362.
Ground-pine, a
club-moss.



FIG. 363.
A lycopodium with
sporangia in the axils of
the frillage leaves

of ferns are borne upon the leaves, and that they are not preceded by flowers. The ferns are members of that numerous class known as flowerless plants or cryptogams. We have thus far studied the flowering plants or phanerogams.



FIG 364.

A true moss, natural size.

428. Although the spore performs the office of "seed" in propagating the plant, it is structurally very unlike a seed. It is not the product of a sexual process, and it contains no embryo. It is a comparatively simple cellular body (very often only a single cell), and is commonly much more minute than any seed. Its formation and germination, therefore, are not comparable with those processes in the seed, and since the beginner cannot see the phenomena for himself, it is useless to describe them here.

428a. The ferns and their allies comprise the class known as pteridophytes or vascular cryptogams, which are green and leaf-bearing flowerless plants having woody bundles or fiber, and vessels, in their stems. Aside from the ferns, the class includes the equisetums or scouring-rushes (Fig. 361), club-mosses (but not the true mosses) and selaginellas. There are nearly three thousand kinds of ferns known. Those who desire to pursue the subject should begin with Underwood's little book, "Our Native Ferns and their Allies," or Dodge's "Ferns and Fern Allies of New England." Persons who desire to study the subject in detail should also have

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FIG. 365.

Cultivated mushroom.



FIG. 366.

Clump of mushrooms.

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432b. In popular usage, the word mushroom is applied to the fleshy and soft plants of this class, and toadstool to the very thin

and fragile ones, but botanists make no distinction in the use of the two terms.

432c. The "spawn" or "brick" used by gardeners in mushroom-growing is simply dried mycelium contained in a mass of more or less decomposed vegetable matter, as manure.

433. A plant of a common poisonous mushroom is shown in Fig. 367. Here there is another structure upon the bulb-like base, suggesting a leg of a boot. This is called a volva. The annulus is shown just underneath the pileus.

433a. This volva, which is sometimes beneath the ground, affords the best means of distinguishing the deadly *amanita* from edible mushrooms. There are volvate mushrooms which are wholesome, but one should never incur risk in eating them unless he is perfectly certain as to the identification of the different kinds. In fact, this caution may be applied to all wild mushrooms. Persons who desire to be able to distinguish the edible mushrooms should consult the writings of C. H. Peck, State Botanist of New York, and those of Atkinson in bulletins of the Cornell University Experiment Station; also Gibson's "Our Edible Toadstools and Mushrooms," and Palmer's "Mushrooms of America, Edible and Poisonous." Those who want to cultivate mushrooms should secure Falconer's "Mushrooms: How to Grow Them."

434. All the plants which we have thus far studied have green leaves and twigs. They take in crude food from the soil and also from the air and work them over into complex organic compounds. Usually, only those plants which have green parts (that is, which contain chlorophyll) can do this. The mushroom has no green parts. It, therefore, generally absorbs food which already has been elaborated or organized. That is, plants des-

titute of green parts generally live upon materials which have been elaborated by other organisms.

435. There are two general ways in which this organized food is obtained,—from a living plant, in which case the plant obtaining it is a parasite; from decaying matter, in which case the plant is a saprophyte. Mushrooms live upon decaying materials in the soil, and they are, therefore, saprophytes.

436. Let the pupil place a piece of bread or cheese under a bowl or in a closed dish in a warm, moist place. In a week or two the sample will become moldy. If one has a lens, he can find the sporangia on the ends of delicate branches of the stalks

or hyphæ; or they may sometimes be distinguished by the naked eye. This mold is a saprophytic plant.

437. These colorless (or, at least, non-chlorophyllous) plants of the mushroom, mold, and mildew type are fungi. They are exceedingly numerous,



FIG. 367.

The deadly *amanita*.

both as to kinds and individuals. Some of them, as the potato-blight, black-rot of grape, and apple-seab, are true parasites, deriving their sustenance from the juices of the living host; and some of them



FIG. 368.

Bulb of Easter lily.

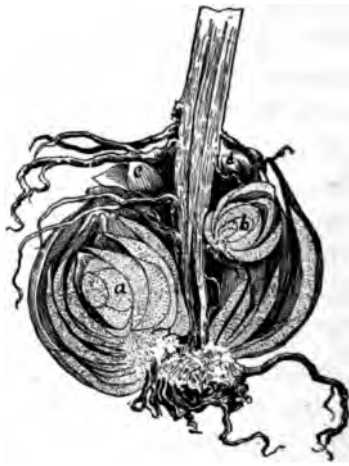


FIG. 369.

Section showing the formation of the bulbels.

are parasitic upon animals and even upon other fungi.

437a. The vegetable kingdom, aside from the bacteria, may be conveniently ranged under four general heads:

Thallophytes — algæ (sea-weeds), lichens, fungi.

Bryophytes — mosses and their allies.

Pteridophytes — ferns, club-mosses, equisetums, and their allies.

Spermatophytes — seed-bearing or flowering plants. Phanerogamous plants is a synonymous term.

437b. The first three divisions comprise the flowerless plants or cryptogams. They far outnumber the flowering plants, both in kinds and in individual plants. Because of their immense numbers, and especially because their structure and life-histories are capable of throwing so much light upon the structure and evolution of plants, the study of the cryptogamous tribes is of the greatest importance to the science of botany.

LXVIII. BULBS, BULBLETS, AND BUDS

438. We have now found that plants propagate themselves by both sexual and sexless means, for seeds are the product of a sexual process, whereas most spores are not.

439. A bulb of an Easter lily, taken after the flowering period is past, is shown in Fig. 368. It is breaking up into several parts; and the gardener knows that each of these parts is a new bulb, and is capable of multiplying the plant.

440. If we cut the bulb in two lengthwise, we find a structure like that shown in Fig. 369. There is a main



FIG. 370.

Onion bulbs.

radish, carrot, parsnip, salsify (Fig. 382) are such. The top or crown is stem, and stands at the surface of the ground ; and from this portion only are young plants or flower-stalks produced. It is strange that while both root-tubers and stem-tubers usually produce sprouts or young plants throughout their length, these crown-tubers do not produce sprouts from the root portion.



FIG. 382.

Crown-tuber of salsify or
"vegetable-oyster."

458. Tubers do not always directly serve the purpose of propagation, but may merely carry the plant over an unpropitious season, and allow it to continue its growth and to resume its normal functions upon the approach of congenial conditions. In fact, beets, turnips, radishes, and other simple crown-tubers are of this class. So are great tribes of cacti, in which the plant-body

directly serve the purpose of propagation, but may merely carry the plant over an unpropitious season, and allow it to



FIG. 383.

Root-tuber of multi-
florus bean.

plates. That is, the lily bulb is a type of a scaly bulb, and the onion of a laminate or tunicated bulb.

441a. One of these onions has a very thick neck or stalk and a comparatively small bulb. The top has grown at the expense of the bottom, and the bulb is worthless for market. Such onions are known as scullions.

442. The onion produces flowers in umbels. Fig. 371 is a bunch of "top onions," in which bulbs (or bulblets) are borne in the flower-cluster. If the pupil examines such a cluster he may find, as in this picture, an umbel bearing flowers, well-formed bulblets, and leaves springing from imperfect or scullion-like bulblets. In other words, flowers have been transformed into purely vegetative parts. (Compare Obs. xxxvii.)

442a. The pupil may have access to the tiger lily, which bears bulblets in the axils of the leaves. Top onions may be had of any seedsman.

443. If bulbs are buds, then we should expect to find various intermediate forms. The house-leek (better known as hen-and-chickens, old-man-and-woman) produces dense rosettes of leaves on the ground (Fig. 372). This rosette is structurally a loose, open-topped bulb. The young rosettes, or offsets, are produced upon short stems from the under side of the rosette, rather than by the

growth of interior parts, as in the lily; but there are some true bulbs which propagate in a similar way.

443a. Let the pupil examine the bulbs of the dog's-tooth violet or "adder's-tongue,"—which gladdens the copses with its nodding bell-like flowers in earliest spring,—for a method of propagation comparable with that of the house-leek.

444. A head of cabbage is cut in two in Fig. 373. It is made up of overlapping and thick-



FIG. 373.

Section of cabbage.

ened leaves, and is really a gigantic bud. There is this important difference between the cabbage and a lily bulb and house-leek rosette, however, that the cabbage bud is not a means of propagating the plant, and one head or bud does not give rise directly to another. It is simply a store-

house; and in this case, the bud has been developed by man through the process of continually selecting for seed plants which have the densest or most coveted buds or heads.

445. We can distinguish bulbs from normal buds, then, by saying that bulbs directly give rise to other bulbs which produce plants; and these plants may produce bulbs directly, or may bear



FIG. 374.

Winter bud of *anacharis*.

FIG. 375.

Winter bud of *myriophyllum*.

seeds which produce plants which produce bulbs. Buds give rise to growing shoots which may produce flowers and seeds, and these seeds produce plants which produce buds. We cannot carry this distinction far, however, because bulbs not only produce other bulbs by lateral growth, but at the same time produce a growing vertical shoot or axis; and we shall find, also, that buds may separate from the parent in essentially the same way that the bulblets of the tiger lily do. The point is that plants may propagate by either sexual or asexual means, or by both means.

446. If one were to pull the water-weeds from the drift on the margins of lakes and ponds in late fall, he would find many of the strands with large bud-like bodies at the ends (Figs. 374, 375). These buds drop to the bottom of the pond, and in spring vegetate and give rise to new plants.

SUGGESTIONS.—Horticulturists raise onions in four ways: by sowing the seed; by planting bulblets (Fig. 371); by "multipliers," which are bulbs that break up into several bulbs during the process of growth; by sets, which are small bulbs that have been purposely arrested in their growth the previous year (by sowing seed in dry ground and allowing the plants to stand very close together) and which, when planted, complete their growth and become merchantable bulbs.

LXIX. CORMS AND ROOTSTOCKS



FIG. 376.

Corm of gladiolus.

447. True bulbs are made up of scales. But there are certain bulb-like bodies which are solid throughout. The gladiolus has them (Fig. 376). These are corms.

448. The corm which was planted in the spring is shown at the bottom (C). It has become hard and lifeless, and a new large corm has formed above it, with roots of its own.

448a. Gardeners say that crocuses "lift out of the ground," and they advise that the "bulbs" be taken up every two or three years and replanted. Can the pupil suggest an explanation?

449. If there were only one new corm formed for every old one, the plant would not increase itself. The picture shows cormels, or "spawn" as the gardeners say, arising from the base of the mother-corm, much as offsets arise from the house-leek (*a*, Fig. 376). If these are removed and cared for, full-grown or flowering corms may be obtained in one or two years.

450. We have found (43, 44, 45) that the early flowering of trees is made possible by the maturation of the bud in the pre-

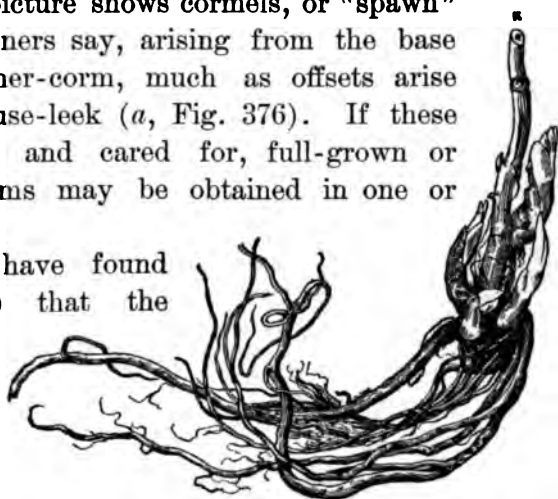


FIG. 377.

Short rhizome of agrimony.

vious season; and the twig stores up sufficient nutriment to push out the flowers, and, in most cases, even to start off the leafy growth. The same is true of much of the early herb growth of spring. In fall or winter, examine the roots of any very early-starting plant and see if great buds are not formed, ready to leap forth with the

first warmth of spring. Fig. 377 is the root and crown of the agrimony, as it was dug up one November day. (See Figs. 278, 279).

451. There is a short corm-like crown, from the bottom of which roots arise, and upon the top of which several strong buds are developed. The old stalk of last year is at *K*. This will not grow again, but new stalks will take its



FIG. 378.

Rhizome of a smilacina.

place; and as new stalks develop the clump or plant becomes larger.

452. The underground parts of the false spike-nard or smilacina are shown in Fig. 378. The specimen was dug in the fall. The stalk which grew during the season of 1897 is at 2. This stalk is now dead, and no other stalk will arise from the same place. The stalk of 1898 is to

arise from the large terminal bud 1; and while that stalk is growing, another terminal bud will form beyond it to provide for the stalk of 1899. We can also trace the history of the plant. The position of the stalk of 1896 is marked by the scar 3; that of 1895 by 4; that of 1894 by 5; and that of 1893 by 6. Beyond that point the parts have died away. There is, then, a progres-



FIG. 379.

Rhizome of quack-grass.

sive movement in this plant. Side branches have started now and then, but they have not made headway.

453. Is this strong underground part of the smilacina a root or stem? It produces definite buds, which roots do not; and it also has nodes. It is a subterranean stem, but roots arise from it.

453a. This subterranean part is a rhizome or rootstock, terms which are applied to creeping underground stems, as distinguished from roots. Some rhizomes bear rudimentary leaves, as that of the quack-grass (Fig. 379), upon which the fibrous leaf-sheaths are prominent. Many rhizomes bear scales at the nodes. Each joint of the rhizome of quack-grass or Canada thistle may grow when broken apart, as the farmer knows to his sorrow.

SUGGESTIONS.—The pupils should have the opportunity to examine rootstocks of various kinds. Good examples are may-apple or mandrake, lily-of-the-valley, canna, peppermint, yellow day-lily or hemerocallis, some of the blue-flags or irises, bloodroot, water-lily, and many sedges; also ginger-root, which may be bought in drug stores.

LXX. TUBEROUS PARTS

454. What is a potato? One is shown in Fig. 380. It has "eyes," or buds, and over each bud is a minute scale which answers to a leaf. The potato tuber does not give rise to roots. It is a stem.

455. What are potatoes for? They are store-houses of food. They carry the plant over the

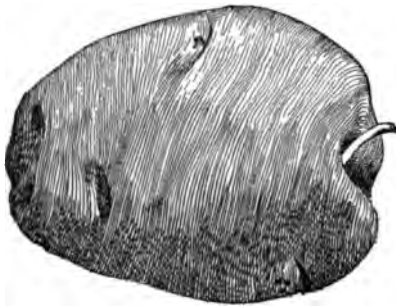


FIG. 380.
Potato.

dry or inactive season (in their native home), and also multiply it by sending forth shoots from every bud. This stored food happens to be nutritious to man, and by cultivation and long-continued selection he has greatly increased the size of the tuber

and refined its contents. But to the plant, the tuber, like a bulb or corm, serves the two pur-

poses of maintaining life during unpropitious seasons and of multiplying the number of individuals.

456. What is a sweet potato? One is shown in Fig. 381. It has no "eyes" or scales. It produces roots. It is a thickened root.



FIG. 381.

Sweet potato.

456a. In botanical writings, a much-thickened and shortened stem is called a tuber; a much thickened root is called a tuberous root. It would probably be better if both were called tubers, one being designated as stem-tuber and the other as root-tuber. Stem-tubers may produce roots from their surface, but they usually do not.

456b. A tuber, then, may be defined as a prominently thickened and homogeneous portion of a root or stem, usually subterranean, and which does not increase or perpetuate itself (as bulbs and corms do) by direct offshoots or accessions.

457. There is a third class of tubers which partakes of the nature of both root and stem. These are sometimes called tubercles, although the name is unfortunate. Dahlia roots, turnip, beet,

radish, carrot, parsnip, salsify (Fig. 382) are such. The top or crown is stem, and stands at the surface of the ground; and from this portion only are young plants or flower-stalks produced. It is strange that while both root-tubers and stem-tubers usually produce sprouts or young plants throughout their length, these crown-tubers do not produce sprouts from the root portion.



FIG. 382.

Crown-tuber of salsify or
"vegetable-oyster."

458. Tubers do not always directly serve the purpose of propagation, but may merely carry the plant over an unpropitious season, and allow it to continue its growth and to resume its normal functions upon the approach of congenial conditions. In fact, beets, turnips, radishes, and other simple crown-tubers are of this class. So are great tribes of cacti, in which the plant-body



FIG. 383.

Root-tuber of multi-
florus bean.

is so much condensed that it may almost be said to be a tuber. A root-tuber of this kind is shown in Fig. 383, which is a picture of a bean of the Scarlet Runner type. (See, also, Figs. 349, 353.) Most beans are fibrous-rooted, and die at the close of one season; but this bean lives two or more years in warm climates, and carries itself over the inactive seasons by means of its



FIG. 384.

Old potato tuber giving rise to new tubers.

thickened root. Even in the North, this thick root develops. It would appear that these thickened parts develop in plants because of the environments in which the plants grow; that is, they seem to be adaptations.

458a. A forcible illustration of the fact that bulbs, corms, tubers, and the like are storehouses of plant-food is suggested by Fig. 384. This represents an old potato tuber (a), from which new tubers have grown, while it was still in the bin. This is a

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frequent occurrence in potato bins in which there are tubers a year or so old. The tuber endeavors to grow, but finding neither light nor soil, it makes new tubers out of its own substance.

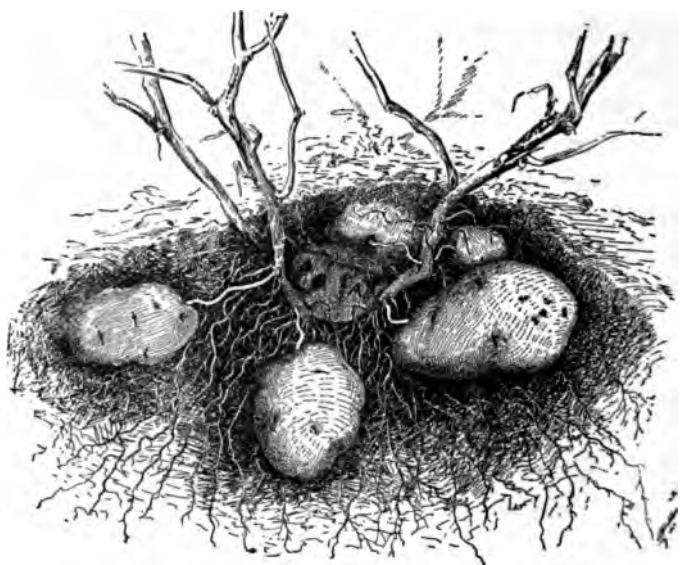


FIG. 385.

Section of a hill of potatoes growing in clay soil, drawn from life.
The old or "seed" tuber is at A.

SUGGESTIONS.—Let the pupil answer some or all of the following questions concerning a hill of potatoes. The queries may all be answered easily by appealing to the growing plants, and some of them may be answered from potatoes in the bin. How early in the life of the plant do the tubers begin to form? Do the tubers grow above the roots or below them? Does the position vary between hard and mellow soils? Are potatoes produced on rhizomes or roots? Do they form on the very end of the underground stalk? Does one stalk ever bear more than one tuber,—do tubers form successively on a stalk, or does a stalk ever branch?

Do these stalks increase in length or diameter after the tuber begins to form? From what part of the plant do these stalks spring? Is there ever a stem on both ends of a potato? From what point do the roots of a potato plant first spring,—from the old "seed" tuber, or from other parts? If an entire tuber is planted, do all the eyes grow?

LXXI. RUNNERS AND LAYERS

459. A stalk or culm of a sedge or carex has fallen to the ground in Fig. 386, and from four of the nodes branches have arisen and from two of them roots have started. These new branches

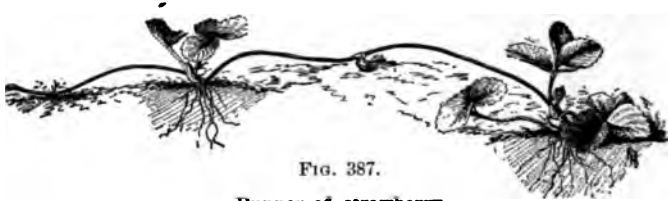


FIG. 386.

Layer of a sedge.

are at first sustained by the parent plant, but as the roots develop from the nodes, the branches become more and more self-sustaining, and finally the old culm rots away and the plants are independent. Such a prostrate rooting shoot is a layer.

460. The strawberry propagates both by seeds and by runners (Fig. 387). In most cultivated



strawberries the runners begin to form after the fruit is off, and a new plant arises from each joint, if the soil is not too hard or the runner is not disturbed. A runner differs from a layer in the fact that it is prostrate from the beginning, and makes new plants while it is increasing in length.

461. Some of the osiers, dewberries, and all the black-cap raspberries propagate by stolons, which are layers that root only or chiefly at or near the tip. Raspberry "tips," with which fruit-growers set a berry plantation, are masses of roots, crowned by a heavy bud, and which have arisen by the end of

the cane striking the ground and taking root, as shown in Fig. 388. A stolon is not prostrate throughout its length, but makes a high loop between the parent plant and its contact with the



FIG. 388.

Stolon of black raspberry.

earth. The shoots which become stolons are at first upright, but the weight of the branch forces the end to the ground.

461a. The practice of layering consists in bending down branches and covering them with earth at the points from which it is desired that new plants arise. Horticulturists make no distinction in terminology between prostrate layers, like that in Fig. 386, and stolons. In plants which root with difficulty, the horticulturist cuts through the bark, or breaks it, at the covered points, for roots usually start more readily from wounded surfaces.

462 We have already studied the house-leek (Fig. 372), and have observed that it propagates by offsets. An offset differs from a layer in the fact that it is prostrate from the beginning, and from a runner because it usually makes but one

plant. It is essentially, however, a special kind of runner. This type of propagation is common.

463. Roots may act as runners. The red raspberry (Fig. 389) and the blackberry are typical examples. Such plants propagate by means of suckers, which are sprouts or shoots arising about



FIG. 389.

Suckers of red raspberry.

the base of the plant from subterranean roots. In common usage, however, any sprout arising through the soil from near the base of a plant is called a sucker, whether it springs from a root or a rootstock. Suckering is one of the commonest means of extending the plant colony; the teacher will recall the lilac, sour or pie cherry, witch-hazel, some varieties of Indian corn, elders, and, in fact, most common bushes.

SUGGESTIONS.—Let the teacher assign each pupil some familiar bush or other plant, asking him to determine if it has any other means of propagation than by seeds. If the plant has suckers, he should determine if they arise from true roots or from rhizomes.

LXXII. THE MANGROVE

464. The mangrove grows on the low shores of tropical lands. It extends as far north as the twenty-ninth parallel in Florida, and occurs at the mouth of the Mississippi and on the coast of Texas. It is a spreading bush, reaching a height of 15 to 25 feet upon the shores, but becoming a tall tree in interior places. It is an important agent in the extension of land into the sea. The means by which this result is accomplished are two.

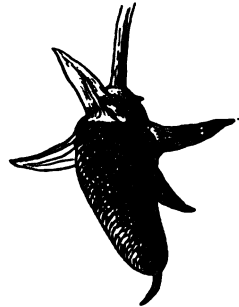


FIG. 390.

The beginning of germination in the mangrove.



FIG. 391.

The hypocotyl enlarging.

465. The fruit is small and capsule-like, but does not fall from the tree at maturity. A fruit is shown natural size in Fig. 390. The seed is germinating, sending its caulicle out through the apex of the fruit. In Fig. 391 the germination is further progressed.

466. In Fig. 392, germination is nearly completed. The seed has endosperm. The cotyledons do not unfold in germination, but a woody tube grows from them and projects from

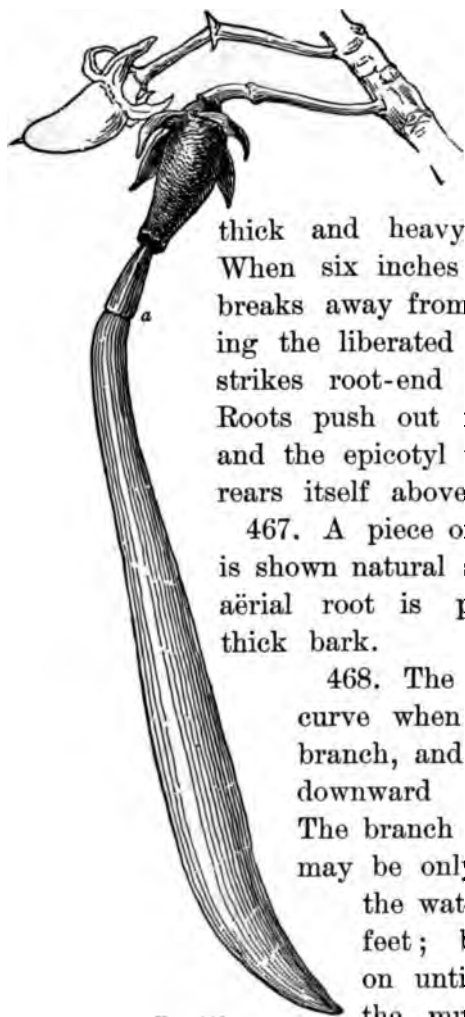


FIG. 392.

The hypocotyl nearly full grown. *a* root system of its own.

the fruit to the point *a*. Inside this tube is the plumule. The hypocotyl continues to elongate, becoming thick and heavy at its lower end. When six inches or a foot long, it breaks away from the joint *a*, carrying the liberated plumule with it, and strikes root-end down in the mud. Roots push out from the lower end, and the epicotyl rapidly elongates and rears itself above the water.

467. A piece of a mangrove branch is shown natural size in Fig. 393. An aerial root is pushing through the thick bark.

468. The root makes a strong curve when it strikes off the branch, and then grows directly downward towards the water. The branch from which it springs may be only a few inches above the water, or it may be ten feet; but the root pushes on until it inserts itself in the mud, and there makes

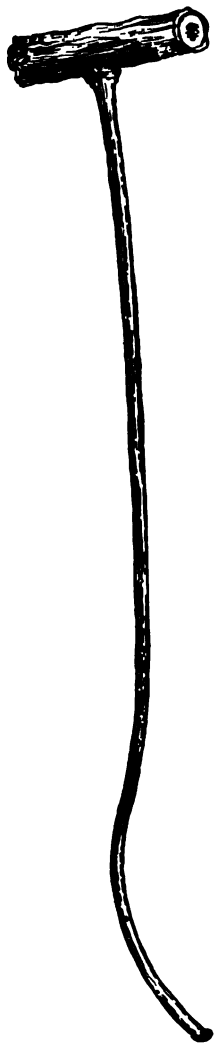


FIG. 394.

The descending root.

These long, lithe descending roots (Fig. 394), swaying in the wind, are characteristic features of the mangrove swamp. Usually the hanging roots are unbranched, but now and then the tip breaks up into short forks (Fig. 395) before it reaches the water.

469. These long roots remain attached at the upper end, and become trunks. The

mangrove plantation, therefore, becomes an interwoven mass, and thus marches on into the tidal rivers and the ocean, catching the flotsam and jetsam of the sea; and thereby it builds land and extends the shores. In the quiet recesses of the mangrove swamp aquatic and amphibious life finds refuge. The shell-fish cling to the trunks and at low tide they are exposed, thus



FIG. 393.

Aërial root of mangrove.

giving rise to the stories of the early explorers that oysters grow on trees.

470. All this will recall the accounts of the banyan tree, and there are wild fig trees (the banyan is a fig) in Florida and southwards which behave in a similar way. It seems strange that roots should strike out into the air, but the pupil may have observed the "brace roots" near the ground on Indian corn; and many plants, as the ivy and trumpet-creeper, climb by means of roots.



FIG. 395.

Multiple tips of a mangrove root-branch.

LXXIII. CUTTINGS AND GRAFTS

471. A plant multiplies itself by means of various sexual and asexual parts which normally detach from it. But it may also spread by means of parts which are torn off by winds and animals, and thus make use of accidents. The branches of willows are broken off by ice and storm, and take root and grow. They are often carried down the streams and drifted upon the shores of lakes, and the branches often take root as readily from the top end as from the bottom end.

472. The leaves of the Mexican bryophyllum (which is often seen in greenhouses) send up plants from their edges when they fall in moist places (Fig. 396). Even the scales of bulbs some-



FIG. 396.

Leaf-colony of bryophyllum.

times produce buds at the base and give rise to new plants; and the horticulturist often utilizes this capacity to increase his stock of new or rare varieties.

473. The stems and even the leaves of some plants produce numerous adventitious plantlets (Figs. 397, 398) while they are still growing on the parent plant, so impatient are they to multiply. It seems as if the vegetable kingdom were redundant with procreative vigor.

474. As reproduction by asexual or vegetative means increases, seed-production tends to decrease.



FIG. 397.

Plantlets on begonia stem.

There are many kinds of plants which are normally nearly or quite seedless, but such plants are always provided with vegetative means of propagation. Many of the pond-weeds are of this class; so are the horse-radish, banana, pineapple and pepino. Even the Canada thistle bears comparatively few seeds, although it blossoms profusely; but it propagates rapidly by underground parts.

475. If nature is so free and undogmatic in her methods of propagation, surely man can devise almost numberless ways in which to multiply his plants. Every plant which propagates from seeds slowly or with difficulty and which is desired to be cultivated man propagates in some manner by asexual parts; and it is probable that every plant can be so multiplied, upon occasion.

476. Of most plants, a bit of soft stem with one or two joints and a leaf or two will grow when severed and placed in the ground under

proper conditions of temperature and moisture. These parts are cuttings (Figs. 399, 400). Nor is it always necessary that the cuttings should be made of stems. They are often made of roots and frequently of leaves. Fig. 401 shows a plant

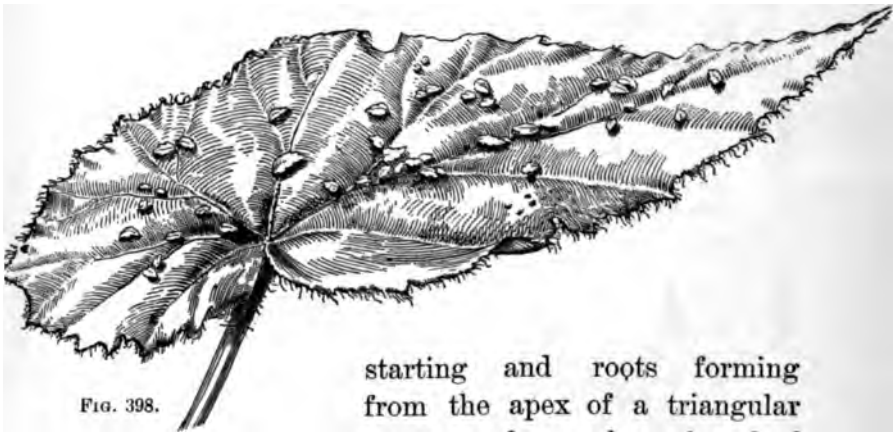


FIG. 398.
Adventitious
plantlets on
begonia leaf.

starting and roots forming
from the apex of a triangular
portion of a begonia leaf

which had been inserted in the soil.

When the farmer plants potatoes, he makes cuttings of tubers.

477. While many stems will grow when planted bottom end up (as the willow often does), making roots indifferently from either end, most root-cuttings persist in making stems only from the end which was uppermost on the plant. Fig. 402 is a picture, from life, of a root-cutting (O, N) of horse-radish, which was planted bottom end up.



FIG. 399.

Cutting of geranium.



FIG. 400.

Cutting of geranium so short that a toothpick is tied to it to hold it erect in the soil.



FIG. 402.

Root-cutting of horse-radish planted bottom end up.



FIG. 401.

Leaf-cutting of begonia.

If the cuttings are allowed to remain in that position, a crooked horse-radish is the result (Fig. 403), although the original cutting will tend to become more or less horizontal. How?



FIG. 403.

Result of the inverted cutting.

478. Nor is it necessary that the cuttings be set in soil. They may be planted in sawdust or moss; and our mothers root oleander cuttings by placing them in bottles of water. Or they may be inserted or planted in another plant, in which case they be-



FIG. 404.

A graft, comprising two clons set in the end of a limb. The exposed surfaces are to be covered with wax.

come grafts (Fig. 404) or "buds." Nor yet is it always necessary that the graft shall be set upon another plant of the same general kind. Horticulturists often graft the pear upon the quince, thereby securing a dwarfer tree because of the slow growth and small stature of the quince; and the plum is often grown upon the peach because of the ease and cheapness of such propagation.

479. The unit in sexual propagation of plants

is the seed. The propagation-unit in vegetative multiplication is the smallest part of root, stem or leaf which will grow when severed from the



FIG. 405.

An ideal hand-glass for cuttings.

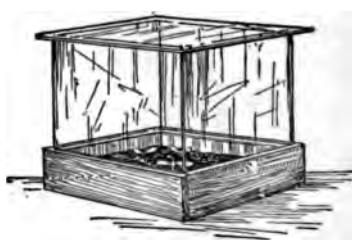


FIG. 406.

A simple and good propagating box made of five panes of glass and a shallow wooden or zinc pan.

parent (although this is not a morphological or structural unit in the plant-body); and, for the purpose of terminology, this part may be called a phyton.

SUGGESTIONS.—Many plants are propagated with the greatest ease by means of cuttings, sometimes even in the school-room window. A miniature greenhouse may be made by laying a pane of glass over a wooden box, and the cutting-bed is made by putting three or four inches of gravelly or sandy soil in the bottom of the box. The sides of the box should not be more than four or five inches high above the top of the soil. The glass cover (which must be raised occasionally for ventilation) will maintain an even temperature and moisture in the box. Better results will be got under bell-jars, or simple glass frames like those in Figs. 405 and 406. Common geraniums are probably the best plants for the learner to begin on. Full directions for the propagation of plants, by all methods, may be found in Bailey's "Nursery-Book."

PART VI

STUDIES OF THE BEHAVIORS AND HABITS OF PLANTS

LXXIV. THE STRUGGLE FOR EXISTENCE

480. We have found that there is struggle for existence, or competition, among the branches of a tree (Obs. iv.), and between the different flowers in a cluster (48); and we have found the same to be true with plants themselves (Obs. lxxv.). It will be profitable to give the subject still further attention. Even without observation, we know that there must be competition in the tree-top, because there would not be room for all the branches if one should arise from every bud; and when the plant is cultivated and the branches made to grow larger,



FIG. 407.

Competition among the
fruits of Indian currant.

because they have more food, the struggle must be still more intense. There is likewise room for many small apples from a cluster, but for only one very large apple. Observe the different sizes of fruits in dense clusters (Fig. 407). If a farmer sows one hundred turnip seeds in a row a foot long, there must be similar competition (Fig. 408).



FIG. 408.

A battle for life.

The weakest, and those which get a poor start, die or subsist on crumbs; but the farmer might have prevented the slaughter by thinner sowing, or he could have cut short the mischief by timely thinning of the plants.

481. If the surface of the earth is now full of plants (412), and if every plant endeavors to multiply itself a hundred fold or a thousand fold, it must result that plants are living under tension.

Whenever plants are destroyed and ground is thereby unoccupied, there is a rush for the place which may be likened to the rush of men to a newly opened and fertile territory.

482. There results a most confused and conglomerate population; but in time certain elements have persisted, and a few kinds of plants occupy the area. A clearing is occupied by the wildest confusion of growths, but, if fire and cattle do not enter, a more or less uniform forest is the outcome. If fire devastates the area, the battle is renewed. If cattle invade, a pasture is the result; and, in the North, the plant which finally gains the victory,—because the one which can withstand the grazing,—is June-grass. The farmer plows his land and kills the plants. A horde of weeds is waiting. If he sows grain, the land is soon occupied and the weeds have little chance; but if his crops occupy only half the ground,—as with beets, potatoes, and melons,—the battle wages the entire season. If he were to leave his well-subdued plowed land to care for itself, the battle would wage most fiercely for a year or two, but the observer would see that the fortunes change, for while ragweed might hold the field one year, mullein might hold it the next, and June-grass might again win the final victory. If his plowed land were full of the roots of briars and other wild

growths, his field might work into a copse and then into a forest, rather than into a meadow. It is the general tendency in all untilled, unburned, and ungrazed lands to run into forests.

483. So there is alternation, or rotation. The land tires of unvaried cropping. The longer any plant occupies an area to the comparative exclusion of others, the greater are the chances that another plant will win the victory if the place is again thrown open to settlement. A poplar forest may succeed the pine.

484. More plants can grow upon any area if they are of diverse kinds than if they are of one kind. An orchard which cannot grow more trees can (and usually does) grow ragweed and docks in abundance. After the land is completely planted to corn, the farmer plants pumpkins between. Meadows of mixed grasses, or grasses and clovers, may give more pounds of hay than those in which there is but a single kind of grass. The introduced weeds and insects which work most havoc are those which are unlike our own plants and insects; they thereby find the field open, as men find a "business opening" where there are fewest competitors. That is, by "divergence of character," as Darwin expressed it, plants are able to live together without demanding space in proportion to their numbers.

485. In other words, struggle for existence does not result in death to all but the strongest: it may result in variation. A plant adapts itself to competition as it does to physical environment. Given struggle for existence,—which is inevitable so long as there is propagation,—and physical changes in the earth,—which we know to have taken place,—and it is impossible to conceive of a perfectly stable and immutable creation. There must be evolution.

485a. The reader must not infer that struggle for existence itself is here specified as a cause of variation. The subject of the causes of variations or differences is the most important one now before naturalists, and it is not the purpose of this book to discuss it. There are some persons who believe that struggle for existence is itself a cause, but others think that it only preserves the most useful of the variations which are already present or potentially present. It is enough for the beginner to know that the struggle for existence results in the perpetuation of differences.

SUGGESTIONS.—The pupil should see the struggle for existence. He should count the dead, and should see what divergencies of characters arise. He has already been instructed (Obs. iv.) how to see it in a tree-top,—by looking. If he wants to see it in separate plants, let him stake off a bit of ground,—say two feet square,—in rich garden soil, allowing the area to remain untouched, and see what happens. He should count the number of plants which come up; observe if they are of uniform strength and vigor; and determine how many kinds there are. He need not know "botany" to be able to designate the kinds; that is, he need not know the names. He may call one kind A and another B. As the season progresses, count at intervals, and observe if some plants are stronger and bigger than others. The teacher may find statistics of such a weed-world in Essay XIV., "Survival of the Unlike."

LXXV. THE DURATION OF PLANTS

486. Beans which are planted in spring complete their span of life and die before the close of the growing season. The plant is an annual.

487. The mullein, bull-thistle and teasel produce spreading rosettes of leaves the first year from seed, the leaves lying nearly flat upon the ground. The next year the seed-stalk, or bushy plant, is thrown up from this crown of leaves; the plant blossoms, produces seeds, and dies. The plant lives two years. It is a biennial.

488. Quack-grass, golden-rods, bleeding-heart, roses, lilac bushes, trees, live on from year to year. They are perennials,—living more than two years.

489. When castor-oil beans, red peppers, cotton and other warm-country plants, are grown at the North, they are killed by the frost. In other words, they do not mature normally in the short seasons; and in their native homes they may be perennials. These are plur-annuals.

489a. A plur-annual, then, is an annual only because it is killed by the closing of the season, as by frost, in distinction to the true annual, which dies at the close of the season, or before, because of natural ripeness or maturity.

490. The annual preserves or perpetuates its kind by means of seeds. Crocuses, potatoes, lilies,

perpetuate themselves by means of tubers or other thickened parts, but both root and stem die upon the approach of the inactive season, or of winter. These are pseud-annuals.

490a. Pseud-annuals ("false-annuals") are those which normally die at the approach of winter, except that the kind is perpetuated by means of bulbs, corms, tubers, and the like.

491. Parsnips and salsify remain in the ground all winter and flower the second season, and die. Turnips and carrots may do the same where the climate is not too severe. But parsnips, turnips, carrots and radishes may "run wild," in which case they may produce no crown-tubers, and may produce seed and die the first year. They are only potential biennials, the biennial character seeming to be largely the result of domestication.

492. We have already learned that bulbs and other thickened parts are storehouses of plant-food, and that they are means, or adaptations, for carrying the plant over an uncongenial season. We have seen, too (489), that plants may be annuals in one climate and perennials in another; or annuals under one set of conditions and biennials under another. It is now believed that the duration of the plant is generally the result of adjustment to the circumstances in which it lives or has lived.

492a. Plants which are widely cultivated generally develop varieties of different durations; and some perennial plants, as tomato and red pepper, have varieties which are almost true annuals in northern countries. Plants which were originally presumably annuals have been developed into potential biennials, as radish and turnip; and on the other hand, the perennial sea-beet is considered to be the parent of the potentially biennial garden beet.

493. Both bleeding-hearts and lilacs are perennials, but one dies to the ground every fall and the other does not. Moreover, the bleeding-heart becomes weak in a few years and dies out, but the lilac retains its vigor year after year. Even perennials, then, may not live always; and there are characteristic differences in their duration. Plants which remain soft and non-woody are herbs. The bleeding-heart,—and every perennial which dies to the ground in the fall,—is an herbaceous perennial.

493a. The horticulturist is well aware that perennial plants may have only a short span of life; else why does he "renew" his beds of grass-pinks, columbines, bluebells, hollyhocks, hardy chrysanthemums, and the like, after they have flowered two or three years?

493b. Flowers which are technically known as annuals among gardeners may be annuals or plur-annuals, or biennials, or even perennials which bloom freely the first year from seed.

LXXVI. THE STATURE AND HABIT OF PLANTS

494. The cherry (Figs. 16, 17), oak, maple, have a single trunk or stem, and we have seen

(Obs. iv.) that the side branches are lopped off or suppressed by competition among themselves and



FIG. 409.

The prostrate habit of mayflower.

with other plants. Plants with a central shaft or trunk, and a more or less elevated head, are trees.

494a. Is it necessary that a cherry or basswood, or other tree, shall grow to a single trunk? If a cherry or peach tree were to grow in the garden wholly without pruning from the first, might it have more than one trunk?

495. In the sumac (Fig. 11) the shaft or leader soon disappears. Compare the lilac and snowball.

These are diffuse and low growers, with no elevated head. They are bushes or shrubs.

496. The mayflower or *epigæa* (Fig. 409) lies upon the ground from the first, making no effort to grow upright. It is prostrate or procumbent. There are, then, two general types of stature,—the vertical and the horizontal; but there is every intermediate gradation.

496a. The general appearance of a plant is called its habit. It may have a prostrate or upright habit, a weak or strong habit, a graceful or rugged habit, and the like.

497. The pupil should determine upon what part of a plant the fruit is borne in raspberries and blackberries. He will find that the stems die, or at least become very weak, and therefore practically useless, as soon as they have borne; and he will see that these stems are only two seasons old. For example, sprouts or shoots spring from the root, in 1896; they bear in 1897. Other shoots arise in 1897; they bear in 1898. The horticulturist knows such shoots—which arise directly from the root, and bear but one or two crops before becoming weak,—as canes.

497a. The raspberries, blackberries, dewberries, are true cane-fruits, but the term is also applied to currants and gooseberries, in which the canes bear several years, although the most profitable crops are obtained the first two or three. The ripened shoots of the grape are also called canes. The pupil will now understand the philosophy of cutting out the canes in raspberry patches.

498. The winter habits of two hickory trees are shown in Figs. 410, 411. The pupil should detect the characteristic differences,—the horizontal growths



FIG. 410.

Pig-nut hickory.



FIG. 411.

Small-fruited shagbark hickory.

of one and the upright growths of the other, and the tortuous, crooked spray as compared with the straighter spray. Every kind of tree and bush has



FIG. 412.
Roots of orchard-grass.



FIG. 413.
Roots of red clover.

a characteristic frame-work or habit of branching. There are great differences between trees in winter as well as in summer, and if the pupil once begins to detect them he will enjoy trees even when they are leafless.

499. The root system of the orchard-grass is shown in Fig. 412. It is fibrous and spreading, not reaching deep into the ground. The root system of clover (Fig. 413) is essentially vertical. The plant has a tap-root or leader, which strikes deep into the soil. Salsify (Fig. 382), turnip, carrot, horse-radish, beet, also have tap-roots, but they are tuberous or fleshy. We have seen (493) that the perennial part in herbaceous plants is subterranean. This part is sometimes stem,—as in bulbs and rhizomes,—and sometimes root; and this root may be tuberous (horse-radish), fibrous and spreading (Fig. 412), or fibrous and tap-rooted (Fig. 413). We have learned, then, that the roots of plants, as well as their tops, have characteristic habits.

499a. In these two Observations we have classified plants in respect to the texture of the plant-body, and to duration and habit. We may fill out the synopsis as follows:

In respect to texture of the plant-body—

Herbs,

suffrutescent, or slightly woody near the ground.

Woody plants,

frutescent (or suffruticose), herbaceous above, but decidedly woody below.

In respect to duration—

Annual,

plur-annual ;
pseud-annual.

Biennial,

potentially biennial.

Perennial,

only part of the plant perennial (herbs) ;
entire plant perennial (woody plants) ;
various differences in the span of life, the herbs, as a
rule, being shorter-lived.

In respect to habit—

Stem horizontal,

creeping or repent (Fig. 386) ;
prostrate or procumbent (Fig. 409) ;
ascending, or rising obliquely upwards, generally from a
more or less prostrate base ;
decumbent or bent over (Fig. 387).

Stem vertical,

shrubby or fruticose ;
tree-like or arborescent.

Root tuberous,

tap-rooted (Fig. 382) ;
fascicle-rooted, as in dahlia.

Root fibrous,

spreading (Fig. 412) ;
tap-rooted (Fig. 413).

SUGGESTIONS.—There is no better subject than the winter aspects of trees to train the pupil's powers of observation. Ask him to look at the different kinds of oaks or maples, or to compare the oaks with the maples, looking at the tree-tops against a winter sky. He will soon begin to catch the differences in outlines and details, and trees will mean more to him ever after. The two hickories in Figs. 410, 411 show minor and unimportant differences as compared with some other trees. Let the pupil put his own emotions into the trees, noting which ones appeal to him as strong, rugged, weep-

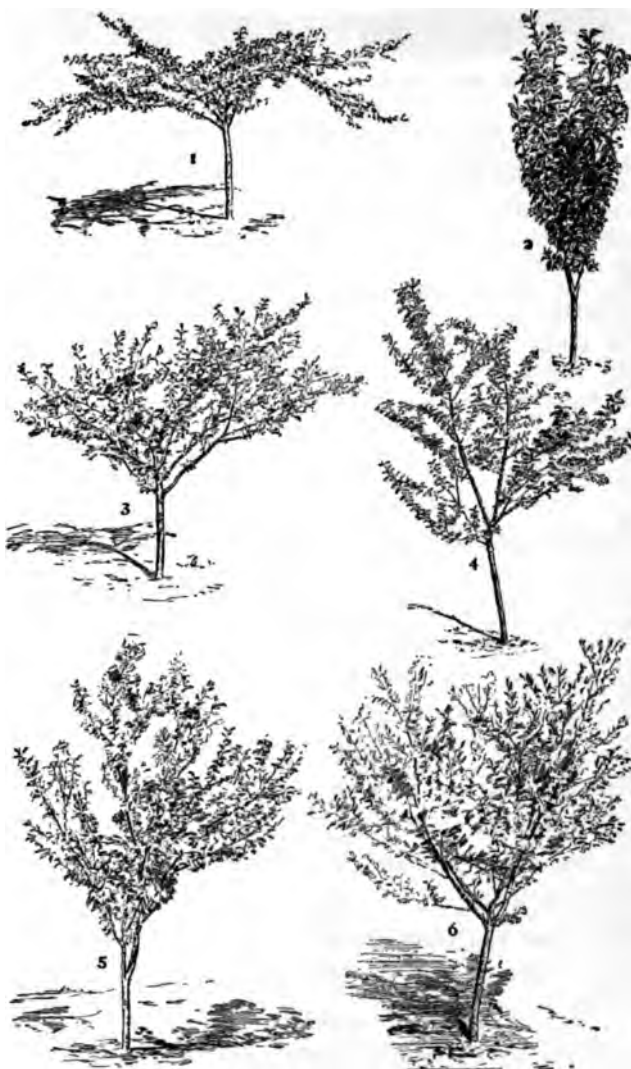


FIG. 414.

Various habits of different varieties of plum.

ing, graceful, bold, and the like. A pear orchard of several varieties is a capital place in which to study differences in aspects of trees. Japanese plums, now considerably cultivated, show marked differences. (The varieties illustrated in Fig. 414 are: 1, Burbank; 2, Wickson; 3, Georgeson; 4, Hale; 5, Abundance; 6, Red June.) In connection with these observations, the pupil may take up the studies suggested in Obs. viii. Suggest to the pupil that he observe the row of shade trees nearest to his home, noting: the comparative vigor or rate of growth of the various trees; the general outline of the tops; the general mode of branching; the character of the twig-growth or spray; and in the summer, whether the trees are equally leafy, and whether the leaves come out and drop at the same time in all of them.

LXXVII. HOW SOME PLANTS GET UP IN THE WORLD

500. The hop reaches light and air by coiling around some support (Fig. 415). If the pupil has access to a hop-field (hops often grow on old fences) or to the Japanese hop of gardens, let him observe the direction in which the stems twine. He will find the tips coiling from his right to his left, or in the direction of the movement of the sun.

501. The morning-glory (Fig. 416) twines in the opposite direction,—from the observer's left to right. Fig. 417 is a morning-glory shoot which was taken from its support, and the free end,—above the string,—coiled about the stake in the

opposite direction. Two hours thereafter, the shoot had uncoiled itself and the tip, as seen in the picture, was again resuming its natural direction.



FIG. 415.

Japanese hop,—with the sun.



FIG. 416.

Morning-glory,—against the sun.



FIG. 417.

Morning-glory refusing to twine with the sun.

We shall expect to find that most kinds of twining plants coil in only one direction.

501a. Plants which coil with the sun, or from the observer's right to left, are known as *sinistrorse* or *eutropic*; those which coil

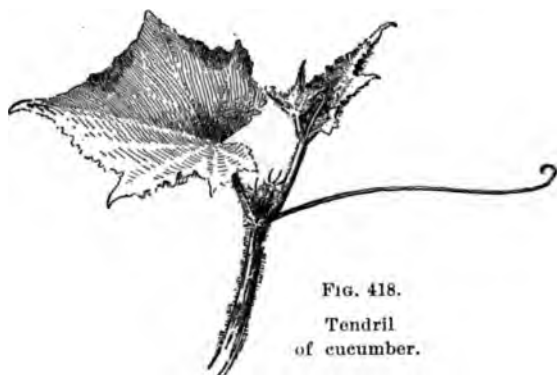


FIG. 418.
Tendril
of cucumber.

against the sun, or left to right, are *dextrorse* or *antitropic*. The latter direction is the more common.

502. Let the pupil watch the free end of a twiner,—as on a young plant which has not yet found a support, or a long tip projecting above a support—and take note of the position or direction of the tip at different times of the day. He will find that the tip revolves in a plane, as if seeking a support.

503. The cucumber climbs by means of tendrils (Fig. 418). Notice that the tendril is hooked, in readiness to catch a support. Does the point of the tendril revolve? Watch it closely; or draw

a mark along one side of it, from base to tip, with indelible ink, and observe if the line be-



FIG. 419.

Tendrils of cassabanana, a melon-like plant.

comes twisted, or if it is now seen on the concave side of the tendril and then on the convex side.

504. The tendril finally strikes a support. What then? It coils; but if it coils much, why does it not twist in two, since both base and tip are fixed? Study Fig. 419. At *a* the branches of the tendril are searching for a support. At *b*

two of the branches have found support, and have coiled spirally, thereby drawing the plant

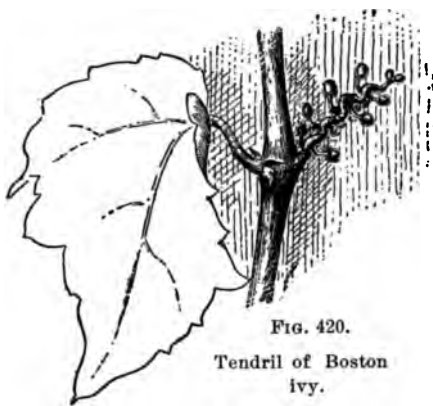


FIG. 420.

Tendrils of Boston
ivy.

near the support; but notice that there are places in each where one coil is missing. At these places, the direction of the coil was changed. The middle branch failed to find a support, and has twisted up

into a querl; and the same thing has occurred in *c*.

504a. Farmers' boys say that a watermelon is ripe when the querl is dead (which, however, may not be true). What is this querl?

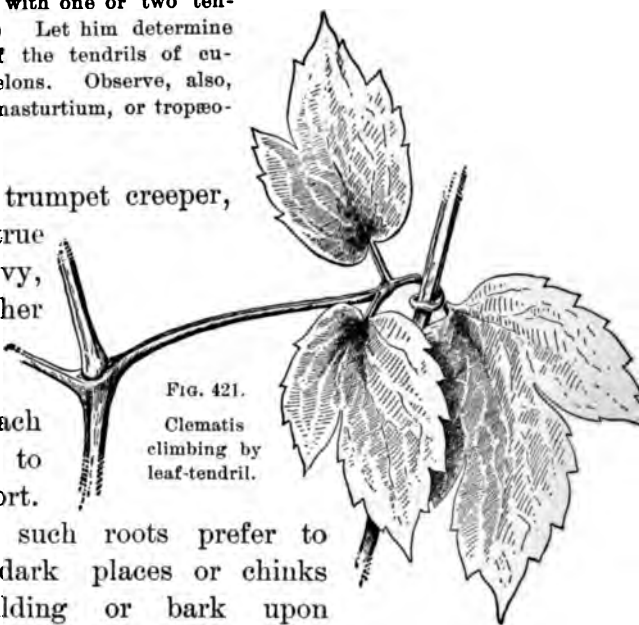
504b. The tendrils of some plants are provided with discs at the ends, rather than hooks, by means of which they attach to a support. Compare the common Virginia creeper; also the root-like tendrils of the Japanese ampelopsis or Boston ivy (Fig. 420). Can the pupil show that the tendril in Fig. 420 is stem, not root?

505. A clematis is shown in Fig. 421. Here the petiolule of the terminal leaflet is acting as a tendril, although all of the petiolules and the petiole have the same habit. Leaves, then, may act both as tendrils and foliage.

505a. This recalls our discussion (Obs. xviii.) of the disguises of leaves, for we then found that leaflets may be represented by tendrils. If the pupil will study the position of tendrils of the grape, he will find that they occupy the places of flower-clusters. (Has he not seen a bunch of grapes with one or two tendrils protruding?) Let him determine the morphology of the tendrils of cucumbers and melons. Observe, also, how the garden nasturtium, or *tropaeolum*, climbs.

506. The trumpet creeper, poison ivy, true or English ivy, and some other plants, climb by roots which attach themselves to the support.

Observe that such roots prefer to occupy the dark places or chinks on the building or bark upon which they climb.



507. Many plants are mere scramblers, as some tall forms of blackberries, galiums (Fig. 63), some of the smart-weed tribe or polygonums. Such plants are often provided with various hooks or prickles by means of which they are secured to the support as they grow; but it by no means follows that all hooks or prickles on plants serve

such a purpose, or, in fact, that they were developed primarily as a means of enabling the plant to climb.

SUGGESTIONS.—We have thus seen how some plants are able to maintain themselves in the fierce struggle for existence. Let the pupil observe if climbing plants naturally grow with other and tall plants, or do they frequent places of less competition and run their chances of finding support on other things than growing plants. Does the climbing habit impress the pupil as being a means of enabling the plant to reach light and air? In respect to the methods by which plants climb, any climber will afford interesting study, but the teacher will find young morning-glory, pea, pole bean, Japanese hop, cucumber, and nasturtium plants to be easily grown from seeds and useful in demonstration. Darwin's "Movements and Habits of Climbing Plants" should be consulted.

LXXVIII. VARIOUS MOVEMENTS OF PLANTS

508. With Fig. 82 we studied the form of the leaf of bean, but there is more to be seen in the picture. The leaf at the left was drawn in the day-time, that at the right in the night-time. There are similar differences in the positions of leaflets of oxalis (Figs. 422, 423) or wood-sorrel. Observe, also, at day and night, the leaves of clovers, lupines, locusts and acacias. In other words, the leaflets and leaves of many plants, notably of the Leguminosæ, take different positions at day and at night. The leaves of some plants close up during very hot hours of the day. The

leaves of purslane, and even of Indian corn and grasses, seem to wilt or to roll up when the weather is hot, and loss of moisture is thereby prevented.

509. The flower of the California poppy, or *eschscholtzia*, which is common in gardens, opens at day and closes at night. Observe, also, the flower of "pussley", the garden

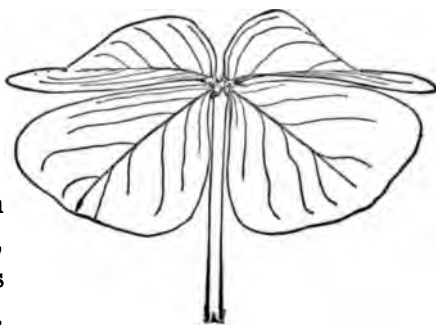


FIG. 422.

Day position of oxalis leaflets.

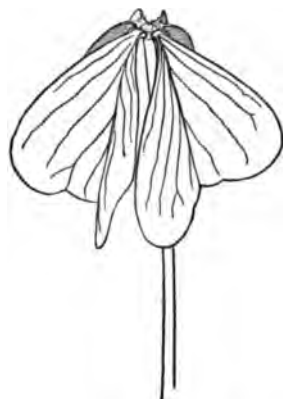


FIG. 423.

Night position of oxalis leaflets.

portulaca or rose-moss, oxalis, and some of the mallows. Other flowers open at night and close at day. This diurnal movement of the parts of plants is known as the "sleep of plants."

509a. It is not a sleep, however, in the sense of being a rest or period of recuperation for the plant. How these movements are produced is not definitely known, but they are associated intimately with the stimuli exerted by light and darkness, heat and cold. The utility of the movement is also in dispute. Darwin found that the position of sleeping leaves at night is such as to conserve the vital heat of the plant, and it is possible that some of this leaf-movement has arisen as

a direct means of adaptation to circumstances or as a protection to the plant; but in the present state of our knowledge, this is largely assumption.

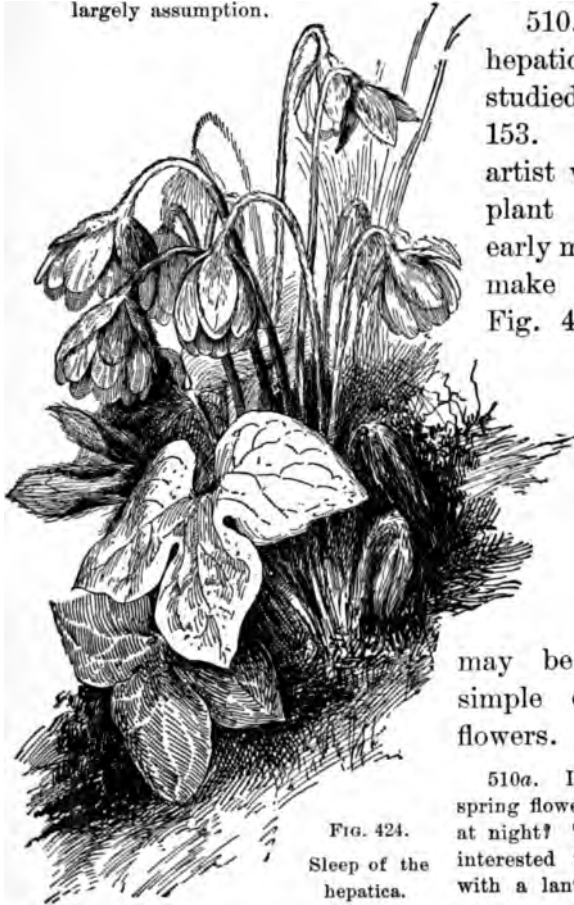


FIG. 424.
Sleep of the
hepatica.

510. The flowers of hepatica have been studied in Figs. 131 and 153. If, however, the artist were to draw the plant at night or in early morning, he would make a picture like Fig. 424. The entire flower droops by the bending of the scape, and it straightens up and expands in the day-time. The sleep of plants, then, may be more than a simple closing of the flowers.

510a. Is it common for early spring flowers to close or to droop at night? The pupil may now be interested to explore the garden with a lantern.

511. One of the most remarkable movements in plants is that of the leaf and leaflets of the

sensitive plant (Fig. 425). The normal position of the leaf is shown at the right. A slight touch or shock causes the petiole to drop and the leaflets to shut up, as shown on the left. The movements are rapid and striking.

511a. The sensitive plant (*Mimosa pudica*) is easily grown from seeds, which may be obtained of seedsmen. It thrives wher-

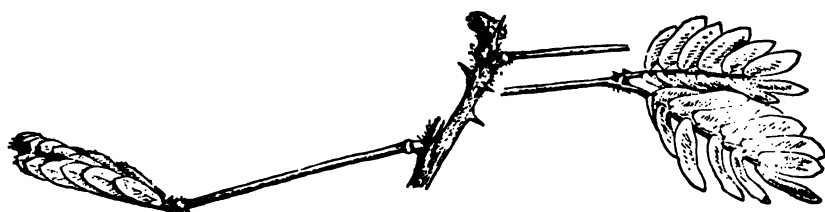


FIG. 425.

The curious behavior of the sensitive plant.

ever beans will grow. The young plants, which grow rapidly, are more sensitive than old ones. The sensitive plant is one of the Leguminosæ.

512. We have now seen movements in stamens (Fig. 150), in leaves, the opening and closing of flowers, the shoots of twining plants and of tendrils, the fly-catchers of insectivorous plants (109a), of stems towards light, and roots towards the earth (405a) and darkness (506), the bursting of pods (316, 316a, 316b, 331); and there are other movements which we have not considered. Plants are not as fixed and as unresponsive to external conditions as we have thought them to be.

SUGGESTIONS.—Darwin's "Power of Movements in Plants" is the first literature to be consulted in connection with the foregoing subjects. Geddes' "Chapters in Modern Botany" will also be useful. Let the pupil grow beans in pots or boxes and watch the positions of the young leaves at midday, at dusk, in darkness, in early morning. The flowers of the common yellow and violet oxalises of window gardens, or the ice-plant, are useful for observation. So are some of the cacti, if the pupil has access to them in bloom. On a hot day the pupil should disturb the stamens in the little yellow flowers of the purslane, and watch the movements.

LXXIX. EPIPHYTES, PARASITES AND SAPROPHYTES

513. Our attention has already been called to the fact (Obs. lxvii.) that some plants are parasitic, obtaining their nourishment from living plants or animals, and that others are saprophytic, obtaining their food from decaying organic matter. These are the robbers and beggars of the vegetable world.

514. The American mistletoe (Fig. 426) is common upon walnuts and other deciduous trees from the Ohio river southwards. It is a spreading evergreen bush, bearing flowers and berries freely. The sticky berries are carried by birds, and the seeds, dropping in the crevices of bark, germinate and send a root-like portion through the bark and into the live tissue beneath. From this live tissue food (see 542a) is abstracted; and

as the branch of the host increases in diameter, the woody tissue is piled up about the imbedded stem (*S*) of the mistletoe (Fig. 427). The parasite is not entirely helpless, however, for it has green leaves and twigs, and is thereby able to elaborate materials taken from the air.



FIG. 426.

American mistletoe growing on a walnut branch.

515. The dodder (Fig. 428) spreads its blanched orange and yellow threads over the weeds in low places, often covering them almost completely by August or September; and certain kinds smother the clover and flax. They are complete par-



FIG. 427.

Attachment of the mistletoe to its host.

asites, having no leaf-green with which to help themselves. The dodders are closely allied to the morning-glories (and to the sweet potato!) and are twiners. The seeds fall to the ground and germinate tardily in the spring, a slender root enters the ground, and a very slender top, supported chiefly by the nourishment in the seed,

reaches from side to side for a host. Finding none, it finally dies; but rank weeds and bushes



FIG. 428.
A plant in the grasp
of dodder.

are usually abundant in the moist places in which it grows.

516. The Indian pipe or corpse-plant (Fig. 429) is frequent in woods. It is wholly destitute of leaf-green and must, therefore, be either a para-

site or saprophyte. It is probable that it is both, deriving some of its nourishment from the roots of living trees, and also some of it from the decaying leaf-mold. There are several leafless and non-chlorophyllous plants growing upon the ground in woods in this country, living much as the Indian pipe does. Some of them are orchids; others are known as beech-drops, because occurring in beech woods; another is the remarkable snow-plant or *sarcodes* of the Sierras. There are, also, quite a number of green and leafy herbs which are partially parasitic upon roots, and which the uninformed observer would never suspect of such habits.



FIG. 429.

The Indian pipe.

517. The lichen, or "moss," which grows upon trees derives its nourishment from the air and rain, and possibly somewhat from the decaying

bark of the host. There is, then, a third class of these dependent plants,—the epiphytes, or those which perch or grow upon other plants, without obtaining food from their juices. They are only squatters, not robbers. The "Spanish moss" of the South,—which is really a flowering plant,—is an epiphyte or air-plant, and so are many flowering plants in southern Florida and the tropics. The pupil may see epiphytes in the better green-houses, where many kinds of epiphytic orchids are grown upon pieces of bark or in hanging baskets without soil; he may also find stag's-horn fern in some of these houses.

518. We have been impressed with the fact of the struggle for existence from a mere mathematical calculation of the rate of propagation; we have seen some of the ways in which plants are able to live together because of differences or divergencies in character; and we are now again impressed with the stress under which plants must live, when we see the unusual places and habits into which they are forced.

LXXX. PLANT SOCIETIES

519. The pupil knows that every different place,—as swamp, hill, ravine, shore,—has its

peculiar kinds of plants. He may not know the plants, but he knows that they look different in the different places. That is, the physiognomy of any place is determined not alone by its physical features,—as elevation, soil, rock, water,—but in large part by its vegetation.

519a. The plants of any region are known, collectively, as its flora. Thus, we speak of the flora of America, or the flora of a meadow.

520. This means that plants live together in communities, those which are suited to the same physical environments and to each other being driven together by the force of circumstances. Local gardens have the same kind of weeds salt marshes the same grasses and weeds, mill-ponds the same herbs. Pigweeds do not grow in woods, nor dandelions in marshes, nor skunk-cabbage on lawns. There are, then, two things to be considered in the plant societies,—the fact that certain plants associate, and the fact that any one plant is not equally distributed everywhere.

521. Let the pupil observe any plant society with which he often comes in contact, for the purpose of determining what plants give it its particular tone or character. The society may be the flora of a familiar roadside or of a fence-row. In some societies, he will find the physiognomy to be the result of an approximately equal blend-

ing of several or even many kinds of plants. In others, he will find that one kind strongly predominates and gives character to the flora; and this is especially true of roadside floras, where migration is unimpeded.

522. If he watch this society throughout the season, he will observe that its physiognomy, or appearance, changes from month to month; and this change is not always such as comes from the greater age and maturity of the plants, but it is often the result of a progression or rotation in the kinds of plants. If the September physiognomy is normally one of aster or goldenrod, what are the May and July characters? And are the asters usually preceded by the same types of plants year by year and in various localities, or are they preceded by any early-flowering plant, indiscriminately?

523. If any society of plants is under tension, it must follow that the withdrawal or modification of any environmental factor will be followed by changes in the flora and, consequently, in the physiognomy. Let the pupil observe how a drain put through a swale affects the flora, or how the felling of the timber affects the undergrowth. The farmer knows that sheep keep down bushes, from their fondness for browsing; when sheep are removed from a copse or thicket, notice how soon

it fills up with strange growths. Pastured woodlands are usually destitute of underbrush.

523a. The observation of these little and local plant societies will prepare the pupil to understand the problems involved in the greater societies which comprise the world-floras. Four great types of societies are, —

Hydrophytic, comprising aquatic floras or those of very humid regions;

Mesophytic, comprising mid-condition floras;

Halophytic, salt-area floras;

Xerophytic, desert or dry-country floras.

The best literature upon this subject is Warming's "*Ökologische Pflanzengeographie*," which is now being rendered into English.

524. The study or science which treats of all these inter-relationships of organisms and their relations to environment is known as ecology (written *oecology* in lexicons). It is the study of the modes of life and habits of animals and plants.

SUGGESTIONS.—Older pupils may be assigned certain local floras to investigate. One may be asked to report what kinds of plants lend the peculiar appearance to an adjacent field, and another may report upon a certain piece of roadside, or upon a lawn, meadow, or garden. Ask a pupil to discover what kinds of plants grow where dandelions, docks, or sorrel do; or what trees grow in woods where basswoods or beeches or oaks or pines predominate. What kinds of plants usually grow in fence-corners? Are they the same kinds that grow in woods? Are the weeds that grow in meadows or in wheat-fields of the same kind as those in gardens? It is not necessary that the pupils or the teacher know the names of all the plants. Let the pupils bring specimens. Pupils will enjoy readings from Gaye's "*The Great World's Farm*." More general discussions of some of the phases of ecology may be found

in Marsh's "The Earth as Modified by Human Action." Teachers who desire to acquaint themselves with the scientific methods of working out the details of plant societies, should consult MacMillan's "Observations on the Distribution of Plants Along Shore at Lake of the Woods," in Minnesota Botanical Studies, Bulletin 9, Parts x. and xi.

Pupils often hesitate to collect plants for fear of being poisoned, but there are only two plants, at least in the Northern States, which are poisonous to the touch. These are the poison ivy (Fig. 84), which climbs on fences, stumps and trees by means of roots, and the poison sumac or poison oak (Fig. 85), a low bush inhabiting swales. The Virginia creeper (Fig. 79) is often confounded with the poison ivy, but it has five, and sometimes more, leaflets whereas the ivy has but three. The Virginia creeper is harmless. Of course, the pupil should never eat of wild fruits or roots without knowing the plant.

LXXXI. RECORDS OF THE SEASONS AND THE YEARS

525. The blooming of certain plants is associated with the coming of spring. The dandelions, the red maple, red-bud, hepaticas, and their train of woods flowers, the fruit-trees, the peeping of the frogs and the return of the birds, all mark the opening of a new season. No one goes to a thermometer or barometer to see when spring has come. In other words, plants and animals move with the seasons, and afford, therefore, the best records of the seasons.

526. The keeping of the dates of blooming,

leafing, and falling of the leaves of certain plants is, therefore, of interest, not only from the side of plant-study, but from the side of climate-study. Plants record all the features of the passing climate, as warmth, moisture, sunshine, and the various inter-relations of them. The science or study which considers the relationship of local climate to the periodical phenomena of animals and plants is phenology.

526a. Phenology is a contraction of phenomenology. It is to be noted that its proper subject is climate, as expressed in terms of plant and animal periodicities, not plants and animals as influenced by climate.

527. If data are to have any value in recording the changes of the seasons, and the climates of the years, they must be made with a definite purpose, and be continued for a series of years; and, so far as possible, records should be taken from the same plants year by year, if these plants represent average conditions.

528. The subjects of phenological inquiry may be classified as follows: to determine the general oncoming of spring; to determine the fitful or variable features of spring; to determine the epoch of the full activity of the advancing season; to determine the active physiological epoch of the year; to determine the maturation of the season; to determine the oncoming of the decline of fall; to determine the

approach of winter ; to determine the features of the winter epoch ; to determine the fleeting or fugitive epochs of the year.

528a. It is evident that any miscellaneous set of notes will satisfy none of these purposes, unless, possibly, the last. Such plants must be selected as will give unequivocal periods, and which are convenient for observation year by year. The observer must feel that records are valuable in proportion to the number of years over which they extend. Except in determining fugitive epochs, observations of a single season alone have little value. For full instructions upon the taking of phenological observations, see Bailey in *Monthly Weather Review of the United States Weather Bureau*, September, 1896.

528b. Five tests of good phenological observations are as follows :

1. As broad a distribution as possible of the plant selected for observation.
2. Ease and certainty of identifying the definite phases which are to be observed.
3. The utility of the observations as regards biological questions, such as the vegetative periods, time of ripening, etc.
4. Representation of the entire period of vegetation.
5. Consideration of those species which are found in almost all published observations, and especially of those whose development is not influenced by momentary or accidental circumstances, as the dandelion is.

529. There are four epochs which are most important in taking phenological notes ; upper surface of leaf first showing ; first flower open ; first fruit ripe or full colored ; half or more of the leaves full colored. If, however, one desires to record only the opening of spring in the various years, only the first two events may be noted. In rural communities, the dates of planting and harvesting of the

leading crops may afford most valuable records. In making notes, it is best to choose common and easily recognized plants, so that the records can be compared and duplicated in other places.

529a. Plants which appear to be most valuable for the main phenological observations and for the greater number of observers in New York and New England are as follows, it being understood that the observer shall designate, as far as possible, the particular variety which he has recorded in the case of cultivated plants:

Apple, pear, quince, plum, sweet cherry, sour cherry, peach, choke cherry (*Prunus Virginiana*), wild black cherry (*Prunus serotina*), Japanese or flowering quince (*Pyrus Japonica*), cultivated raspberry, cultivated blackberry, cultivated strawberry, lilac, mock-orange or syringa (*Philadelphus coronarius*), horse-chestnut, red-pith elder (*Sambucus racemosa*), common elder (*Sambucus Canadensis*), flowering dogwood (*Cornus florida*), native basswood, native chestnut, privet or privet (*Ligustrum vulgare*), red currant, cultivated grape.

529b. For the fugitive or abnormal epochs of the year, as "warm spells" in winter or spring, or "late falls," and the killing frosts of fall and late spring, the observer must consider whatever plants come in his way. Here is the chief value of the dandelion in phenological records;—it should not be included in any general scheme of notes. There is the greatest temptation to record the blooming of the very earliest spring flowers, as mayflower or epigea, hepatica, erigenia, dandelion, willows, crocus, and the like. This is well, and the records should be made, as showing the first burst of spring; but these records should not be mixed in with those designed to show the general onward course of the seasons.

SUGGESTIONS.—There is a common passion to make dates of the opening of the spring flowers and the leafing of the trees, and in order that this desire may be guided and directed into useful channels, this chapter has been inserted. Suppose that dates were kept of the blooming, or leafing, or falling of the leaves, of certain trees or other plants in the school premises, or of the appearing of the dandelions. The habit might soon become a tradition in the school, and the records be continued from teacher to teacher. Or, the pupil might be asked

to choose some plant at his own home of which he would take records from year to year. Wholly aside from the possible value of such notes as records of climate, the note-taking would define and direct the pupil's observation.

LXXXII. THE BREEDING OF PLANTS

530. We have been impressed with the fact that plants are adapted or fitted to the conditions in which they grow, and we believe that much of this adaptation has come to pass because those variations which were best fitted to live in the given conditions did live and perpetuated their kind, and the others perished. If we personify nature, we may say that she selects the fit and discards the unfit. This is the hypothesis of natural selection, or Darwinism.

531. The gardener sows a row of lettuce. He sows more seeds than he desires plants, knowing that some seeds may not grow and some of the young plants may die or be injured. When the plants are well up, he thins them, taking out, perhaps, two-thirds of them; but he always leaves the largest and best, and it is from these best plants that seeds are saved. This is a process of selection, and is comparable with natural selection.

532. The original parents of domestic plants were wild plants; but the domestic plants finally became very unlike the plants from which they

sprung. The process which has caused them to be more and more unlike the parents is continued selection,—the choosing of the best or most coveted, generation after generation. Sometimes this selection has been intended, the person desiring to improve the breed. For the most part, however, it has been unintended and generally unconscious, the person thinking only of the excellence of the present crop; but the result, nevertheless, has been the improvement of the race.

533. The kind of lettuce plants which are left is determined by the person who thins the row. One person may like broad-leaved lettuce and another may want long-leaved lettuce. As no two persons have the same likes and dislikes, so no two would thin the row in exactly the same way. The result is that, in time, two persons would obtain different types or strains of lettuce, if they continually raised their own seed. That is, the evolution or amelioration of domestic plants is directed by personal ideals. The plant-breeder must first conceive of his variety, then produce it.

534. Neither natural selection nor human selection can operate until variations have occurred. We have said (485*a*) that naturalists are disputing as to the original causes of variation, but the horticulturist knows how to start off variations. Any change in the conditions in which the plant grows

will do it. More heat, less heat, more food, less food, more water, training, growing under glass or in the shade or in the sun,—these and other factors



FIG. 430.

Forms of the wild and cultivated dahlia.
Half natural size.

which the horticulturist has at his control cause, or at least bring out, differences in plants; or he can produce differences by crossing (Obs. xlv). The variation is the start; selection does the rest.

535. The wild dahlia and a cultivated variety are shown in Fig. 430. How was it done? The wild kind was cultivated. It got better care and more food than it had in its native Mexican home, and

all the conditions of its life were changed. It began to vary. Just what factor or set of factors caused these variations we shall never know; but one variation produced an abnormal number of rays (probably because of more food supply and

redundant vigor), and the gardener liked it. He sowed the seed, and from the plant bearing the most doubled flowers again sowed the seed. It was only a question of perseverance, a uniform ideal, and time.

535a. The teacher who desires to enquire further into these subjects may consult "Plant-Breeding" and "Survival of the Unlike."

LXXXIII. UPON WHAT DOES A PLANT LIVE?

536. The plantlet at first lives upon the nutriment stored in the seed, or in the tuber or bulb. But it soon must shift for itself. Plant it in a small pot which has been filled with firmly compacted earth. In a short time the pot will be filled with roots, and the plant is pot-bound. Secure a large pot-bound plant from a greenhouse. Turn it upside down and knock off the pot, as a gardener does. How could such a root-growth take place in a space already full? Shake out the earth from the roots, and add it to that which remains in the pot. Is there as much earth as there was before the plant was set in it? Will the earth now fill the pot as full as it was when the plant was set?

537. Secure a large topped, pot-bound plant. When the earth is fairly dry, remove the pot

and place the plant with its ball of remaining earth (which is probably larger in amount than that extracted by the plant) in a horizontal position, and balance it upon the finger. Are the stem and top heavier than the root and earth combined? The plant has not only consumed some of the earth, but it has derived food from other sources.

538. There are but two sources from which this extra food can be obtained,—from the water applied to the roots, and from the atmosphere. The pupil cannot determine if the plant lives from these two sources of nourishment, except that he knows that the plant dies in the absence of either water or air.

539. He must be told, then, how the plant lives. It absorbs substances in solution by means of its roots. (Consider the root-hairs.) Water must be present, or the soil materials cannot be dissolved. The water, therefore, acts as a carrier of food; but the plant also uses the elements of water itself as foods. The elements which the plant takes in through its roots are many, but those required in large quantity are potassium, sodium, calcium, phosphorus, silicon; others are necessary.

540. The plant absorbs gases by its leaves, chiefly carbon dioxid, which consists of carbon

and oxygen; and from this invisible source the plant derives its carbon, which makes up nearly half its entire weight, aside from the water.

541. The materials taken in by the roots and leaves cannot be used directly in the making of plant tissue and in contributing to growth. They must be worked over, or formed into organic compounds. This process of elaboration takes place in the green parts, chiefly in the leaves, and in the presence of sunlight. Plants destitute of green, or chlorophyll, mostly use food which is already organized: they are parasites and saprophytes. The withdrawal of sunlight, as in the banking-up of celery, destroys the chlorophyll.



FIG. 431.

Trunk girdled by a wire.

542. When the food has been elaborated, it can be utilized, through further changes, for the building of tissue, and it is distributed throughout all living parts of the plant, even to the roots whence part of it came. The process of changing the inorganic materials into organic materials,—or assimilation,—takes place only in daylight; but the transfer and subsequent use of the elaborated food

may take place more freely in darkness. So it comes that most of the growth in plants is made at night.

542a. Since the plant cannot directly use, in the making of tissue, the materials which are taken in from the soil and air, it has been proposed that the term food be not applied to them; but the application of the terms food and plant-food to these raw materials is so thoroughly established in scientific literature that it seems to be unwise to attempt to change it.

543. The trunk of a young tree girdled by a label wire is shown in Fig. 431. It is larger above the girdle. There has been more rapid growth at that point, and we suspect that the cutting of the bark by the wire prevented the distribution of the elaborated food to the part below the girdle. In time, then, the root must starve, even though it collects food. The crude materials taken in by the root pass upwards in the young wood,—the sap-wood,—by a process which is not yet well understood. The elaborated materials are redistributed through parts of the inner bark. There is no circulation in plants in the sense in which there is in animals,—through definite tubes or openings.

543a. There are many good and recent books upon the physiology of plants, treating the subject from various points of view. One of them, by Arthur, is now upon the press.

PART VII

STUDIES OF THE KINDS OF PLANTS

LXXXIV. SPECIES

544. Plants live where and how they must. They adapt themselves to conditions by varying. It must generally happen that the most marked variations tend to persist, because most unlike others, and therefore better able to find places of least competition. The intermediates must tend to die out. In time there come to be wide divergencies or differences; or, different kinds have originated.

545. It was once supposed that these kinds were created as they are in the beginning. These kinds were conceived, therefore, to be original units or entities in nature; and if they are real things, remaining forever essentially the same, they must have a name. They were called species.

546. But there are various kinds and degrees of differences, and there early arose dispute as to what kinds are the real original species and what

are merely incidental variations of them. So those kinds which an author thought to be the originally created things were called the species, and the lesser kinds were called varieties.

547. It was soon apparent, however, that authors differed widely as to what were species and what varieties. The species of one writer became the varieties of another. The very fact that the kinds varied so widely that they could not be uniformly named, is evidence that they are not real and original things in the creation. but are the outcomes or results of modification. As a matter of practice, while authors define species to be entities in the creation, they apply names and descriptions to forms because they are distinct enough to be easily recognized, without enquiring as to whether these forms answer a definition or not. In other words, species have always been regarded, in practice, merely as assemblages of similar individuals.

548. We now believe that plants have been changing throughout all time, and that some kinds have been widely separated and are distinct (that is, not connected to others by intermediate forms), and that others are not yet clearly differentiated from their kin. In other words, species are results of evolution, not original parts of the creation; and just what degree of difference shall constitute a species is a matter of individual judgment. Species

are human conceptions,—the names of groups of similar individuals,—enabling us to write and speak of the forms of life. A species may be defined as the unit in classification, designating an assemblage of organisms which, in the judgment of any person, is so marked and homogeneous that it can be conveniently spoken of as one thing.

549. It does not matter, therefore, whether different botanists agree or not as to what are species and what varieties of species, so long as one is able to understand what the other means. By giving names to the objects which we see, we are able to classify and to put on record our knowledge of them.

LXXXV. THE NAMING OF SPECIES

550. It is necessary that we have names for the kinds of plants. We must have a language. Plants were first known by common-language names, but obviously only common and conspicuous plants can receive such names; and since most people do not distinguish the kinds of plants closely, it follows that common names cannot be applied with precision. Most early authors described plants in Latin phrases, referring similar

kinds to a common group or genus; and the name of this genus was made the first word in the description.

551. Linnæus, who attempted to name and describe all plants and animals, used a single word, which, when joined to the genus name, should designate the species. This word was placed in the margin of his book, and the Latin description, headed by the genus name, ran as before. There thus arose a binomial system of nomenclature.

551a. A fac-simile reproduction of Linnæus' description of the Fox-grape is here inserted (from "Species Plantarum," second edition):

3. VITIS foliis cordatis subtrilobis dentatis subtus to- Labrusca, mentosis.

Vitis hederæ folio serrato. Plum. spec. 18. ic. 259. f. 1.

Vitis sylvestris virginiana. Baux. pin. 299.

Vitis vinifera sylvestris americana, foliis averſa parte denſa lanugine rectis. Pluk. phyt. 249. f. 1.

Vitis fructu minore rubro acerbo, folio subrotundo minus laciniato, subtus alba lanugine recto. Sloan. hist. 2. p. 104. t. 210. f. 4.

Habitat in America ſeptentrionali. ‡.

Vitis is the genus name, and *Labrusca* the species name. The combination, *Vitis Labrusca*, is the name of the plant.

551b. It is probable that Linnæus did not foresee the commanding place which his system of nomenclature was destined to fill. The specific name was apparently intended for little more than a marginal index to the descriptions. It was Linnæus' successors and editors who made the combination of the generic and specific names take precedence of the description, and who thereby stereotyped it into an arbitrary and irrevocable name of the plant.

552. Kinds of plants which, in the judgment of any author, are not distinct enough to be called species, are called varieties; and the full designation of the variety is rendered in three words, — the generic, specific and varietal names.

552a. Thus, the name of the black maple is commonly written *Acer saccharinum*, var. *nigrum*; but there are some botanists who prefer to regard it as a species and to call it *Acer nigrum*. This



FIG. 432.

Spray of black maple.

maple affords a good illustration of the different views which may be held as to the name and classification of any plant. The black maple is shown in Figs. 432 and 263; the sugar maple, in Figs. 433 and 262. They are distinct enough; but in some regions they are so much alike (they "run into each other") that botanists prefer to regard them as one species.

553. It often happens that two authors inadvertently give the same name to different plants. It is, therefore, customary to cite the author of the name, or an abbreviation of his name, with

the name of the plant. The author's name, therefore, identifies the plant name, and facilitates the tracing of it to the place of original description. We therefore write the name of the Fox-grape, *Vitis Labrusca* L. (the L standing for Linnæus).

553a. With the multiplication of writings describing plants, it becomes more and more important that names be easily identified,



FIG. 433.

Spray of sugar maple.

and that authors use more care in referring to other writers who may have mentioned or described the plant. The quotation in 551a shows how carefully Linnæus cited the places in which that particular *vitis* had been described.

554. By common consent, no two plants are allowed to have the same name. Therefore, when a person names a plant, he must be sure that

that particular combination of generic and specific name was never used before.

555. By common consent, also, the name first given to a plant must always be used to designate it; and all subsequent names are cited as synonyms. While this rule of priority is a most important one in the naming of plants, there are exceptions to it. For example, the rule that the same name shall not be used for two plants, takes precedence. If an author should inadvertently make a name which had been used before, his name may be set aside and a new one substituted. If an author considers that any species is in the wrong genus, he may transfer it to another, and a new combination of names is the result; but, by custom, he must use the same specific name in the new genus unless that name is already in use in that genus.

555a. Thus, the wild crab-apple is generally referred to the genus *Pyrus*, and it is known as *Pyrus coronaria*. But there are some authors who would divide *Pyrus* into several genera, one of which is *Malus*, the apples. The crab then becomes *Malus coronaria*.

555b. The specific names may be common adjectives, as *coronaria*, agreeing in gender with the name of the genus; proper adjectives, as *Americana*, *Smithiana*, also agreeing with the genus; proper names in the genitive, as *Smithii*; or substantives, as *Labrusca*, used in apposition to the generic name. Some botanists write the proper names and substantives with a capital initial, but others use no capital for specific names.

555c. Binomial nomenclature, as now used and understood, be-

gins with Linnæus. The first edition of his "Species Plantarum," 1753, is now commonly taken as the starting point. Linnæus lived and taught in Upsala, Sweden.

LXXXVI. THE CLASSIFICATION OF SPECIES

556. More than 100,000 species of flowering plants are known, and it is probable that nearly as many more await discovery. It is evident that if this vast number of facts is to be studied, the facts must be arranged or classified.

557. A classification may serve merely as a convenience in arranging and systematizing knowledge of objects; or it may also attempt to express some hypothesis of the kinships of the objects themselves. In other words, it may be an artificial system, or a natural system.

558. The first great system of classification of plants was that of Linnæus, who has been called "the father of botany." It was wholly artificial, in the sense that it made no attempt to classify plants according to their relationships. The vegetable world was first divided into classes founded upon the numbers and positions of stamens. These classes were divided into orders founded upon the numbers of styles or stigmas. The Linnæan system comprised twenty-four classes; and each of the first thirteen classes was divided

into twelve orders. Thus a plant with four stamens and six pistils was referable to Class Te-



FIG. 434.

Linnaeus (1707-1778). Reproduced and adapted from "Species Plantarum," second edition, 1762.

trandria ("four stamens"), Order Hexagynia ("six styles").

559. But there are certain great resemblances in plants which allow them to be grouped into natural assemblages. These assemblages we now call families (240a). Linnaeus recognized such groups, as had others before him; but Jussieu

was the first to clearly outline them (in 1789), and to arrange the known genera in their proper families. From this time, the family, rather than the species, became the unit in the natural systems of classification.

560. There are two methods or schemes of arranging the families of plants, of which, among the flowering plants, there are over two hundred. One method conceives of an ideal type of plant, and places that family first which most nearly satisfies this ideal. De Candolle conceived the ideal or pattern flower to be one with all the parts present, free and distinct. The crowfoot family, or Ranunculaceæ, contains such plants as its types, and this family was placed first in the classification. Our familiar systematic botanies are arranged upon the De Candollean plan, or modifications of it.

561. The other method tries to make a classification which shall represent the course of evolution of the vegetable creation. It places first those plants which are simplest and most generalized in structure, or which we have reason to believe appeared first in time. These systems begin with the flowerless plants; and they generally end with the composites.

561a. The De Candollean sequence of families is the most familiar system, particularly in English-speaking countries. It is essentially the method of Bentham and Hooker's great "Genera Planta-

rum" (London, 1862—1883). In this country it has been followed, with only minor variations, in all the taxonomic works of Asa Gray, the greatest American systematist. The general acceptance of the



FIG. 435.

Asa Gray. 1810—1888.

evolution-method of creation, however, is causing systematists to break away from the older systems. At present the sequence of Engler & Prantl's "Die Natürlichen Pflanzenfamilien" is probably most favorably received.

562. The evolution systems must be the systems of the future, for they afford the convenience of a classification at the same time that they suggest genealogical relationships. The teacher must be warned, however, that it is impossible to represent a perfectly true classification,—that is, a natural one,—in a book, from the fact that the classification must be lineal or successive, whereas we know evolution to have been a series of divergencies.

563. In other words, evolution has not progressed in a line, but in the form of a tree. Branch after branch has been given off. Some branches have long since reached their development and are dying out; others are still growing. We must not expect, therefore, that present types of flowering plants came from present types of flowerless plants, merely because the latter are placed first or lowest in the scale of classification. Probably both came from a common ancestor in remote time; and this ancestor may be lost.

564. The present forms of vegetation, then, are the tips of the branches of the tree of life. Therefore, the "missing links" are to be sought behind, not between: they are ancestors, not intermediates.

SUGGESTIONS.—When the pupil has acquired a good knowledge of the parts of the plant, he will be interested in the bolder strokes in schemes of classification. Let the teacher take any systematic

botany which may be at hand, and place the outlines or skeleton of the classification on the blackboard. This outline may usually be obtained from the table of contents or the introductory key. Under each heading or group, write the names of one or more familiar plants, in order to fix the system in the mind. The pupil should be impressed with the fact that all systems of classification yet devised are imperfect and more or less tentative, but that they serve a purpose, nevertheless, in arranging and classifying our knowledge. As more knowledge is obtained respecting the kinships of plants, new arrangements of the species and other groups must be made.

LXXXVII. THE PRESERVING OF PLANTS

565. If the kinds of plants are to be carefully studied, specimens must be preserved. The plants of an entire region can then be seen, and, what is more important, they can be seen side by side, for comparative study is the only productive method in systematic or descriptive botany.

566. The plants are preserved by drying them under pressure. These dried and pressed plants are then secured to sheets of large white, stiff paper (Fig. 436), and the sheets are filed away in covers, as leaves of music are placed in a portfolio. The covers are laid flat in a cupboard or cabinet. Such a collection of plants is an herbarium.

567. Although the specimens shrink some in drying and flowers often lose their color, these

dried plants preserve their distinctive characters remarkably well. It is from such specimens that



FIG. 436.

An herbarium sheet.

most descriptions of plants are made; and a person who proposes a new species always preserves

a specimen of it as a record. In case of doubt as to what the species is, the specimen, rather than the description, is consulted.

568. A label (Fig. 437) should always accompany the specimen, and be securely glued to the sheet. The size, form and style of label are

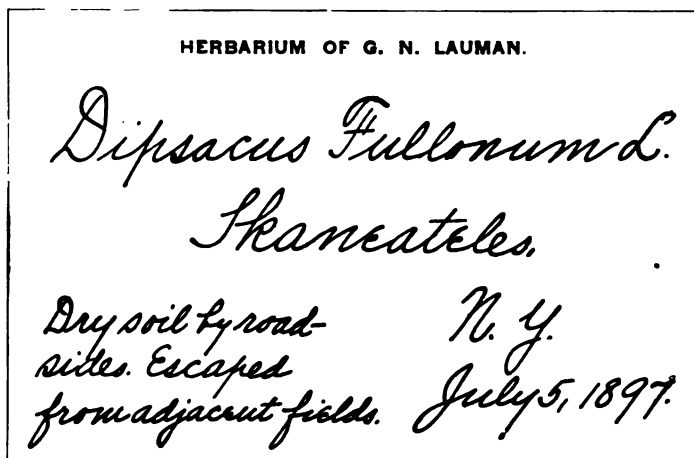


FIG. 437.

An herbarium label.

governed by the wishes of the maker of the herbarium; but the label should give the name of the plant, where and when collected, and any incidental information, as to soil, location, color of flowers, height of plant, which is likely to be useful.

569. The collecting of the plants is botanizing. The first requisite is a tin case or vasculum (Fig. 438), in which the plants are placed, as collected. The specimens are pressed when the collector arrives home. If the vasculum closes tight, the

specimens will remain in good condition for several hours. If they wilt too rapidly they may be lightly sprinkled with water. Upon journeys or long tramps, a portable press is sometimes used (shown in Fig. 438), the pressure being applied by means of straps. The most important point to be considered in collecting plants is to make sure that the specimen is large enough and good enough to fairly repre-



FIG. 438.

Collecting outfit.

sent the plant from which it is taken. A good specimen is one which is well pressed and which comprises leaves, flowers and fruit; and a complete specimen is one which represents every part of the plant, including the root.

570. It is important to remember that common plants are most useful for study, and several specimens should be taken, representing different soils and conditions. If one begins with the thought of securing only the rare, curious or beautiful things, he will probably have an herbarium which is of no particular value. He will have only a collection of detached plants. Some theme or motive should run through a collection,—to exhibit the flora of a neighborhood or a roadside, to illustrate the plants of a forest or a garden, to show the effects of different environments, and the like.

570a. In collecting plants, always set out with the ambition to make good specimens. Collect samples of all parts of the plant,—lower and upper leaves, stem, flowers, fruit, and, wherever practicable, roots. In small species, those two feet high or less, the whole plant should be taken. Of larger plants, take portions about a foot long. Press the plants between papers or "driers." These driers may be any thick porous paper, as blotting-paper or carpet-paper, or, for plants that are not succulent or very juicy, newspapers in several thicknesses may be used. It is best to place the specimens in sheets of thin paper—grocer's tea-paper is good—and place these sheets between the driers. Many specimens can be placed in a pile. On top of the pile place a short board and a weight of thirty or forty pounds, or a lighter weight if the pile is small and the plants are soft. Change the driers every day. The plants are dry when they become brittle, and when no moisture can be felt by the fingers. Some plants will dry in two or three days, while others require as many weeks. If the pressing is properly done, the specimens will come out smooth and flat, and the leaves will usually be green, although some plants always turn black in drying.

570b. Specimens are usually mounted on single sheets of white paper of the stiffness of very heavy writing-paper or thin Bristol-board. The standard size of sheet is $11\frac{1}{2} \times 16\frac{1}{2}$ inches. The plants may be pasted down permanently and entirely to the sheet, or they may be held on by strips of gummed paper (as in Fig. 436). In the former case, Dennison's fish-glue is a good material to use. Only one species or variety should be placed on a sheet. Specimens which are taller than the length of a sheet should be doubled over when they are pressed. The species of a genus are collected into a genus cover. This cover is a folded sheet of heavy manila or other firm paper, and the standard size, when folded, is $12 \times 16\frac{1}{2}$ inches. On the lower left-hand corner of this cover the name of the genus is written. The specimens are now ready to be filed away. If insects attack the specimens, they may be destroyed by fumes of bisulphide of carbon (which is very inflammable) or chloroform. In this case it is necessary to place the specimens in a tight box and then insert the liquid. Lumps of camphor placed in the cabinet are useful in keeping away insects. Those who wish detailed information on the collecting of plants should consult W. W. Bailey's "Botanical Collector's Handbook." For methods of making leaf prints and of preserving flowers in natural colors (and of collecting and preserving insects), consult Chap. XV. of Bailey's "Horticulturist's Rule-Book," 4th edition.

570c. The naming of the specimens must be accomplished with the aid of some manual of the plants of the region. There are several books to aid in this work; but the teacher should bear in mind the important fact that the name of a plant is less important than the plant itself, and effort should not be expended in this direction at the expense of the study of the specimens. By making herbaria of the various forms of common species of plants, much of the labor of mere identification is avoided. The name of a plant serves two purposes: it affords language which we can use in speaking or writing of the plant, and it serves as an index to whatever may have been written about the plant.

570d. The standard systematic work upon the plants of North America is Gray's "Synoptical Flora," which, however, is not yet completed. For that part of the United States east of the Mississippi and north of Tennessee, and practically including adjacent Canada, Gray's "Manual," now in its sixth edition, is the standard

authority. Britton and Brown's new "Illustrated Flora," in three volumes and with an illustration of every species, covers essentially the same territory as the manual, with the addition of the British Possessions as far north as Newfoundland. Macoun's "Catalogue of Canadian Plants," in several parts, and published by the Geological and Natural History Survey of Canada, may be consulted for the British Possessions. For the southern states east of the Mississippi, the third edition of Chapman's "Flora of the Southern States" is the standard reference. For the territory west of the Mississippi there is no single manual. The floras covering parts of this region are: Coulter's "Manual of the Botany of the Rocky Mountain Region," and "Flora of Western Texas," the latter published by the United States Department of Agriculture; Greene's "Manual of the Botany of the Region of San Francisco Bay," for central California; Howell's "Flora of Northwest America," for Oregon, Washington and Idaho. For the common wild and cultivated plants of the United States east of the Mississippi, the revision of Gray's "Field, Forest and Garden Botany" should be consulted. Books of a more popular nature may often be used by teacher or pupils, as Mrs. Dana's "How to Know the Wild Flowers," Mathews' "Familiar Flowers of Field and Garden," W. W. Bailey's "Among Rhode Island Wild Flowers," Baldwin's "Orchids of New England," Newhall's books upon "Trees," "Shrubs," and "Vines," Knobel's Guides ("Trees and Shrubs," "Ferns and Evergreens" of New England), and others. There are many excellent local floras,—books devoted to the plants of a state, county, or small circumscribed geographical area. Other systematic books are mentioned in paragraphs 263a, 428a, 433a; Suggestions, p. 289.

SUGGESTIONS.—The collecting of natural objects is one of the delights of youth. Its interest lies not only in the securing of the objects themselves, but it appeals to the desire for adventure and exploration. Botanizing should be encouraged; yet there are cautions to be observed. The herbarium should be a means, not an end. To have collected and mounted a hundred plants is no merit; but to have collected ten plants which represent some theme or problem is eminently useful. Schools usually require that the pupils make an herbarium of a given number of specimens, but this is scarcely worth the effort. Let the teacher set each collector a problem. One pupil may make an herbarium representing all the plants of a given swale, or fence-row, or garden; another may en-

deavor to show all the forms or variations of the dandelion, pigweed, apple tree, timothy, or red clover; another may collect all the plants on his father's farm, or all the weeds in a given field; another may present an herbarium showing all the forest trees or all the kinds of fruit trees of the neighborhood; and so on. The collector should be asked to display his herbarium to the school, explaining the problem in hand; and the teacher and others may then criticise the making of the specimens. The teacher should discourage the collection of plants simply because they are rare; and an effort should be made to preserve in their natural locations the interesting and showy wild flowers, rather than to destroy them by over-zealous collecting.



FIG. 439.

The botanist's resort on a rainy day.

APPENDIX

SUGGESTIONS AND REVIEWS

As a consequence of the informal nature of this book, remarks upon related topics are often widely separated. It may facilitate the teacher's work if some of these topics are epitomized.

1. SUGGESTIONS UPON PEDAGOGICAL METHODS

A somewhat full discussion of the author's opinions respecting the methods of presenting nature-study by means of plant-subjects, is given in the Introduction. It is desired to emphasize the importance of making nature-study objects the subjects of writing and drawing in schools in which composition and drawing are taught. The first essential to the writing of compositions is that the pupil have something to say which is drawn from experience and observation. Live and emphatic ideas are more important than drill in modes of expression. Fill the pupil with his subject, and writing comes easy, particularly if he is taught that good English demands that he go no farther with his subject than to express what he himself feels. The writing and the drawing should not be intended, primarily, as examinations in the nature-study, but as regular exercises in the customary work of composition and drawing.

Teachers sometimes like to take up the plant as an entirety, before discussing its parts. Familiar plants may be brought before the class, and the different parts pointed out,—as stems, roots, leaves, flowers. This is desirable with children, but its usefulness is commonly not great, except as a brief introduction to more serious observation. The pupil should be taught to see accurately and in detail; and it is always well to lead him to make suggestions as to the meaning and uses of the features which he has seen. When the pupil has obtained a clear idea of any part or member,—as of

the simple leaf, pinnate leaf, tap-root, stamen, petal,—let him compare this member in many kinds of common plants. For example, let him study and draw the leaves of all the maples of the region, the stamens in the blossoms of orchard fruits, the acorns of all the obtainable oaks, the roots of the root-crops of gardens and fields, the pappus of the common composites, and the like.

Some of the pedagogical remarks which have been dropped from time to time may be found in the following paragraphs: 104, 118, 152*a*, 278*b*, 278*c*, 281, 318, Suggestions page 273, 339, Suggestions page 288, 347*a*, 423, Suggestions page 380, 570, 570*a*, Suggestions page 443.

The author wishes again to emphasize the fact that this volume is not intended as a text-book from which recitations are to be made, but as a bundle of suggestions for teacher and pupil. He does not expect that the conditions will ever occur in which all the subjects can be taken up in the order and method here set forth.

2. BOOKS

Every school, however humble, should own a few books to which the pupils may have access. There are many good books about plants which will be helpful to both teacher and pupil in pursuing the suggestions contained in this volume; but the teacher should bear in mind the important principle that the pupil should have the plant before he has the book. Having seen the object and derived a concrete impression from it, he may go to books to verify his observation and to widen his knowledge. Various books upon specific subjects have been mentioned in the text, in paragraphs:

Books upon special subjects—109*a*, 135*b*, 228*a*, 235*a*, 263*a*, 277*a*, 278*a*, 282*a*, Suggestions page 250, 331*b*, Suggestions page 289, 362*b*, 381*a*, Suggestions page 336, Suggestions page 380, Suggestions page 385, Suggestions page 402, Suggestions page 406, 528*a*, 535*a*, 543*a*, 570*b*, page 452.

Floras and systemic monographs—263*a*, Suggestions page 289, 428*a*, 433*a*, 561*a*, 570*d*.

Other inexpensive books, which may be recommended to the teacher who desires to take up the kind of work suggested in this volume, are:

- Gray's Lessons in Botany for Beginners and for Schools. Revised.
Gray's Structural Botany. Sixth edition. A most complete presentation of the subject in its formal aspects.
Setchell's Laboratory Practice for Beginners in Botany.
Lubbock's Flowers, Fruits and Leaves.
Weed's Ten New England Blossoms and their Insect Visitors.
Willis' Flowering Plants and Ferns. An excellent small cyclopedic work.
Newell's Outlines of Lessons in Botany. In two parts (or volumes).
Excellent for teachers.
Bergen's Elements of Botany.
Goodale's Concerning a Few Common Plants.
Spalding's Guide to the Study of Common Plants.
Darwin's Elements of Botany.
Youmans' Descriptive Botany.
De Candolle's Origin of Cultivated Plants.
Dana's Plants and their Children.
Master's Plant-Life on the Farm.
Goff's Principles of Plant Culture.
Darwin's Variation of Animals and Plants under Domestication.
Allen's Flowers and their Pedigrees.
Newell's Reader in Botany.
Kerner's Natural History of Plants, translated by Oliver. 2 vols.
More expensive than the other works here mentioned, but excellent, particularly for high schools and academies.

3. CLASSIFICATION

We have divided the vegetable creation into two great classes, the flowering plants and the flowerless plants (427, 437*b*). The former are known also as phanerogams and spermatophytes (seed-bearing plants). The latter are cryptogams.

The cryptogams, exclusive of bacteria, have been thrown into three groups (437*a*): Thallophytes; Bryophytes; Pteridophytes or vascular cryptogams (427).

The phanerogams or spermatophytes are divided into gymnosperms and angiosperms (376, 376*a*).

The angiosperms are divided into monocotyledons and dicotyledons (396-398a).

We have seen that certain great assemblages of plants are called families (240a); and some remarks concerning the methods of arranging or classifying these families are made in Obs. lxxxvi.

Various observations touching classification and relationships are made in paragraphs: 187, 241, 242, 244, 246, 247, 247a, 250, 253, 260, 261, 262, 268, 324, 350, 369, 376, 376a, 396-398a, 427, 428a, 428b, 437a, 437b, Obs. lxxxiv., lxxxv., lxxxvi.

4. REMARKS UPON EVOLUTION AND THE INTERPRETATION OF NATURE

While it is no part of the purpose of this book to teach or to explain any of the hypotheses which attempt to account for the ways in which the present forms of life have originated, the book nevertheless assumes that there is evolution and that creation is continuing. This attitude is positively essential to any clear comprehension of the attributes and meaning of the vegetable creation. The reader who wishes to put together the suggestions of this character may consult paragraphs:

Struggle for existence—5, 11, 13, 14, Obs. iv., 48, 80, 223, 305a, 412, 518, Obs. lxxiv., Suggestions page 402.

Variation and selection—35, 71, 118, 118a, 134, 135, 137, 138, 175, 178a, Fig. 172, 208, 227, 233, 302, 315, 331b, 358, 444, 458, 484, 485, 485a, 492, 492a, 518, Obs. lxxxii.

Definitions—53a, 53b, 53c, 258a, 258b, 258c, 423a, 423b, 423c, 548.

Interpretation of nature—116, 117, 118, 118b, 118c, 118d, 138, 152a, 175, 187, 227, 235a, 258, 268, 278b, 278c, 281, 315, 318, 331b, 336, 338, 339, Obs. lxx., 485, 507, 509a, 518, Obs. lxxxiv., 561-564.

Ecology—Obs. lxxx., 422.

5. THE GROWING OF PLANTS

In the Suggestions on page 330 and in Observation lxxiii. (page 374), brief directions have been given for the growing of plants. Wherever there is sunlight and absence of frost, plants may be

grown in the school-house. Even though the plants are not vigorous and do not reach their full development, they add greatly to the interest and efficiency of plant-study. The desire of pupils to see growing plants in the school-house and about the premises has been forced anew upon the author's attention by responses to a humble leaflet upon garden-making which was distributed to public school teachers by the College of Agriculture of the Cornell University. Even in crowded city schools the leaflet bore fruit. The following extracts from letters from Miss Lilian M. Elliot, Pd.M., of New York City, illustrate how plants may be grown under great difficulties (see also, "School Journal" for May 29, 1897):

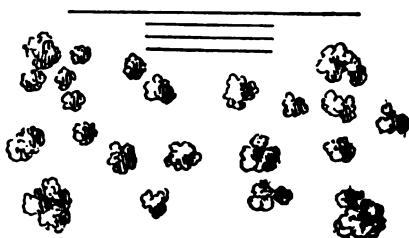


FIG. 440.

A meaningless plantation.

"I received your Nature-Study Leaflets. One of them, 'A Children's Garden,' especially interested me. Of course the paper had a twofold object, the cultivation of the love of nature in the child, and the beautifying of the rural districts. The pleasure that the child can get from this unconscious instruction is limitless, to say nothing of the latent æsthetic side which is awakened. My first feeling was one of disappointment that my poor boys—the majority of whom hail from the poorest and most crowded of our city tenements—should be deprived of another birthright. This idea of yours was so fascinating that I began to think and ponder, until gradually my thoughts took material shape. This is the result:

"Every boy was asked to bring a cigar box. This they could easily do, since both parents of many of them are employed in cigar factories. The covers of the boxes were useless. The boxes were about five inches wide. We took off one side and cut the width to three inches, and then nailed the side on again. We now had a box 8x3x2 inches. The reason we had to make the box narrower was because our desks are so constructed that the firm part which holds the pencils is only three inches wide. It is upon this firm place that we put our boxes. The boys did all the measuring and cutting. The wood is soft, and a pen-knife is a sufficiently strong tool. They then painted the boxes a uniform dark red, and filled them with earth. I bought seeds of aster and sweet peas, as recommended, and allowed the boys to take their choice. We soaked the seeds in warm water over night, and planted them on Arbor Day! They have so far succeeded beyond our most sanguine expectations, and although they are neglected from Fridays until Mondays, most of the plants have thrived remarkably well.

"There are fifty-five boys in the class; I have forty desks in the school. The

boys range in age from ten to fifteen years, and each one is more than interested,—he is wildly enthusiastic. The delicate green on every desk is an effective decoration in the class-room. No time for this work has been taken from the school program. In spite of our overcrowded room, with its more or less unhealthy atmosphere, we have risen triumphant over adverse circumstances, and are in delighted possession of our 'Childrens' Gardens'.

"At the close of school in June, the effect of those forty thriving boxes of green was beautiful! Every visitor admired them. The plants made the room look artistic and refreshingly cool on even the warmest day. These were the first impressions made upon the visitor, but the simple little nature stories that those plants told their rough and neglected owners will last, I am sure, as long as the memory of school days."

Other teachers grew plants in smaller boxes, in pots, and even in egg-shells upon the ledges of the desks.

The out-door garden, however, will always be the chief delight of young and old. If there is any land whatever about the building,

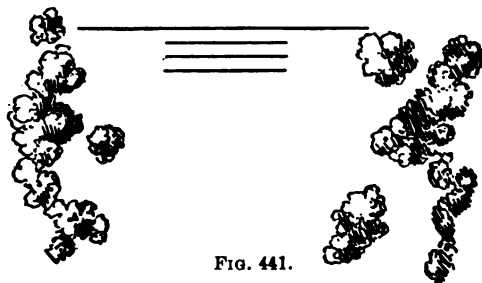


FIG. 441.

The elements of a picture.

many plants can be grown, and with great effect. There are two objects to be attained in the planting of a school-ground,—the making of a picture, and the raising of plants for study. Happily, the two purposes are not contradictory, although the idea of the picture should come first and is more important. If the school-ground is to be a picture, it must appeal to the observer as a unit. Scattered and isolated trees, bushes and flower-beds divide and distract the attention, and fix it upon the details, rather than upon the yard as a whole. The picture is to be attained by accenting the importance of one central and dominating object. This central and supreme object is the school-house. Keep the center of the place open, carpet it with a verdurous lawn, and flank it with irregular groups of trees

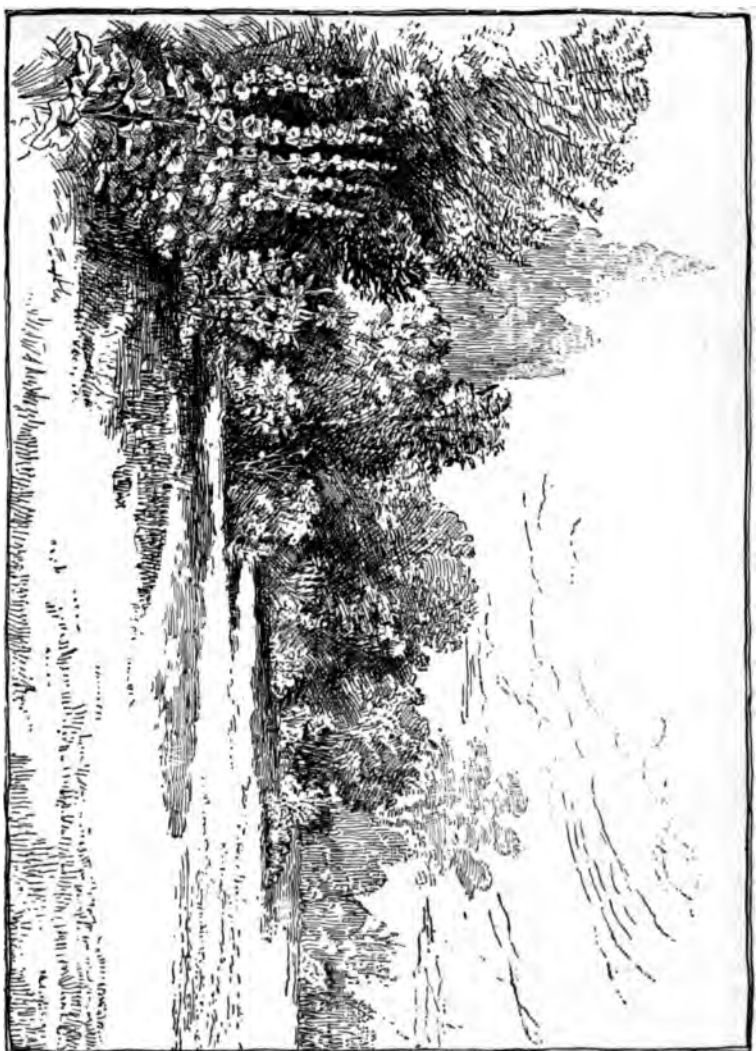


FIG. 442.—A flanking mass of shrubbery and flowers.

and shrubs about the borders. On the devious inner edges of these border-groups, against the back-ground of foliage, is the place for the flowers. The flowers are then a part of the structural design of the picture, and their forms and colors are shown to the best advantage. The sketches illustrate these remarks. Fig. 440 shows a front yard set full of meaningless plants: it is a nursery. Fig. 441 shows the same yard with a dominating central idea and an expanse of canvas or greensward: it is a picture. Fig. 442 shows a planted flank, with its bold edgings of flowers.

If there is only six feet between the school-house and the fence, there is still room for a border of shrubs. This border should be between the walk and the fence,—on the very boundary,—not between the walk and the building, for in the latter case the planting divides the premises and weakens the effect. A space two feet wide will allow of an irregular wall of bushes; and if the area is one hundred feet long, thirty to fifty kinds of shrubs and flowers can be grown to perfection, and the school-grounds will be practically no smaller for the plantation. In country districts and large grounds, effects like that in Fig. 442 can be obtained with little trouble. If there is no money with which to buy shrubs, they can be got from adjacent woods and fields and gardens; and such plants usually thrive best, because they are hardy and well adapted to the region. One week's well-directed work in each year, by one man, coupled with donations of plants from private yards, could make every school-yard in the land a little paradise.

It is an easy matter to make the school premises shown in Fig. 443 to look like Fig. 444. The plan, Fig. 445, suggests the design and method. The place could be still further improved by heavier mass-plantings on the borders. Fig. 446 suggests a plan for a school-yard upon a four-corners, which the pupils enter from three directions. The two playgrounds are separated by a broken group of bushes extending from the building to the rear boundary; but in general, the spaces are kept open, and the heavy border-masses clothe the place and make it home-like. The lineal extent of the group-margins is astonishingly large, and along all these margins flowers may be planted, if desired. A greater amount of effective ornamentation can be secured by planting in narrow belts on these margins than by covering half the entire area of the premises with flowers. More detailed instructions for the planting of gardens may be found in "Garden-Making", and in other horticultural books.



FIG. 443.—Rural school premises.



FIG. 444.—Suggestion for the improvement of the above premises.

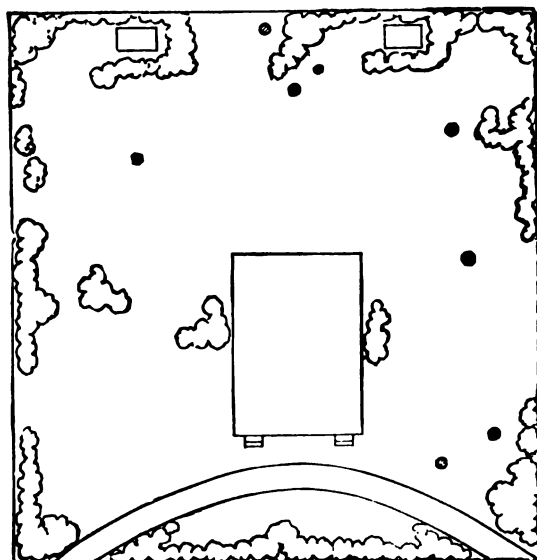


FIG. 445.—Ground plan of the improvement.

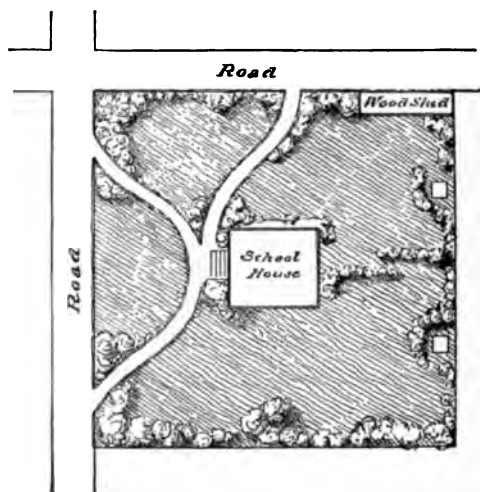


FIG. 446.—Suggestions for the planting of a school-yard upon four corners.

6. GLOSSARY

(Numbers refer to paragraphs.)

- Abrupt.** Suddenly narrowed, as a leaf-blade to the petiole. 132.
- Abruptly pinnate.** Said of a pinnately compound leaf which has all its leaflets in pairs: no extra leaflet at the end. 100.
- Acaulescent.** Stemless, or very nearly so: said of the entire plant.
- Achlamydeous.** Lacking the perianth: naked. 152b.
- Acquired characters.** Those characters or features which arise in any generation as the result of environment or of external stimuli. 423d.
- Acuminate.** Long-pointed. 132.
- Acute.** Sharp or pointed. 132.
- Adaptation.** The fitness of any organ or organism to perform certain functions or to live in certain conditions. 423a.
- Adnate.** Said of an anther attached throughout its length to the filament (162a); also applied to the union of the calyx-tube with the ovary.
- Adventitious.** Said of buds, or of shoots, which appear in abnormal or unaccustomed places or numbers, rather than at nodes and in definite number. 233.
- Adventive.** Said of introduced plants which grow spontaneously, but which are not thoroughly naturalized.
- Æstivation.** The folding of the perianth in the bud. 63.
- Air-plant.** Epiphyte, which see.
- Akene, achenium.** A hard, dry, 1-seeded, indehiscent fruit, especially one in which the pericarp very closely envelops the seed. 290.
- Ament.** Catkin. 176.
- Amplexicaul.** Clasping. 121, Fig. 108.
- Analogy.** Similarity of function or use. 53c.
- Andræcium.** Collective name for the stamens. 152d.
- Androgynous.** Staminate and pistillate flowers borne in the same flower-cluster. 186.
- Anemophilous.** Pollinated by wind. 273a.
- Annual.** A plant which completes its entire life cycle in a single year. 486.
- Annulus.** The ring upon the stipe of mushroom-like fungi, being the remains of the veil.
- Anther.** The enlarged part of a stamen, which bears the pollen. 141.
- Anthesis.** Flowering. 225b.
- Anthotaxy.** Inflorescence. 225b.
- Antitropic.** Dextrorse. 501a.
- Apetalous.** Lacking the corolla. 152b.
- Apical.** Pertaining to the apex or top: in this book, said of pods which open at the top. 309.
- Apocarpous.** Carpels, or simple pistils, not united. 305.

(Numbers refer to paragraphs.)

- Angiosperm.** One of that great class of plants in which the ovules are borne in ovaries. 376.
- Arboreous.** Tree-like.
- Articulated.** Jointed.
- Ascending.** Rising from a more or less prostrate base. 499a.
- Asepalous.** Lacking the calyx. 152b.
- Attenuated.** Tapering.
- Auriculate.** Eared: most commonly used with leaves which have large, narrow basal lobes. 121, 132.
- Axil.** Angle above the junction of a leaf-blade, petiole, peduncle or pedicel with the branch or stalk from which it springs. 2.
- Axile placenta.** A placenta in the center, or on the axis, of an ovary. 158a.
- Banner.** Standard, which see.
- Basin.** In pomological writings, the depression in the apex of a pome. 349.
- Berry.** A fleshy or pulpy fruit, especially if it has small seeds. Lii.
- Bicompound.** Twice compound. 99.
- Biennial.** A plant which lives two years, particularly if it does not fruit until the second year. 487.
- Bigener, bigeneric-hybrid.** A hybrid between species of different genera.
- Bigeneric half-breed.** The product of a cross between varieties of species of different genera.
- Bifid.** With two clefts or parts. 104c.
- Bifoliolate.** With two leaflets. 104a.
- Bilocular.** 2-loculed: 2-celled. 157a.
- Binate.** With two leaflets. 96, Fig. 86.
- Bipalmate.** Twice palmate. 104b.
- Bipinnate.** Twice pinnate. 104b.
- Bisect.** With two segments. 104c.
- Biserial.** A term proposed in this book to designate flowers which have both gynœcium and andrœcium, but no perianth. 152a.
- Bisexual.** Of two sexes: containing both stamens and pistils. 152c.
- Bilernate.** Twice ternate: bi-compound, with parts in threes. 97.
- Blade.** The expanded part of a leaf. 87.
- Bracts.** Reduced leaves. 105.
- Bryophyte.** Term designating the moss-like plants. 437a.
- Bulb.** A large and more or less permanent and fleshy leaf-bud, usually occupying the base of the stem and emitting roots from its under side, and the function of which is to propagate the plant or to carry it over an unpropitious season. Lxviii.
- Bulbel.** A small or secondary bulb borne about a large or mother-bulb.
- Bulblet.** A small bulb borne wholly above ground, as in the inflorescence or in the axil of a leaf. 442.

(Numbers refer to paragraphs.)

- Caducous*. Falling very early, as petals or sepals: not persisting.
- Calyptra*. Hood: technically applied to the covering of the capsule of mosses. 428b.
- Calyptrate*. Covered with a hood: as buds borne beneath the hollow end of a petiole. 37.
- Calyx*. The outer series of the perianth: the sepals. 146.
- Campanulate*. Bell-shaped. 211a, Fig. 176.
- Cane*. A shoot which bears but once, particularly one which arises from the crown or root. 497.
- Capitulum*. Head. 185a.
- Capsule*. A compound pod (310); also the spore-case of a moss. 428b.
- Carpel*. One of the separable or integral parts of a compound pistil. 159
- Caryopsis*. The akene-like fruit of the grasses and cereal grains. 293a.
- Catkin*. A more or less dense, scaly flower-cluster, particularly of certain trees and shrubs: ament. 176.
- Caudicle*. Stemlet: applied technically to the stalk of a pollinium. 279.
- Caulrescent*. Having a stem: said of the entire plant.
- Caulicle*. Stem of the embryo. 408.
- Cavity*. In pomological writings, the depression in the stem end of a pome. 349.
- Cell*. See locule.
- Character*. In natural history writings, a feature or attribute which is diagnostic,—which is peculiar to the part or the organism, and distinguishes it from its kin. viii.
- Chlorophyll*. Leaf-green: the green substance in protoplasm in plants.
- Choripetalous*. Polypetalous.
- Cion*. A cutting set into a plant rather than in soil: graft. 478.
- Circinate*. Coiled from the tip. 62.
- Circumcissile*. The mode of dehiscence of the pyxis. 308. Spelled also circumscissile.
- Cladophyllum*. A branch which imitates a leaf in appearance and structure, and which performs the function of foliage. 114a.
- Claw*. The stalk of a petal. 145.
- Cleft*. In a leaf-blade, a division somewhat more than half the depth of the blade. 104c.
- Cleistogamous*. Said of reduced and closed flowers which are self-fertilized in the bud. 280a.
- Close-fertilization*. Self-fertilization.
- Colored*. Said of parts having any color but green.
- Column*. The body formed by the union of gynoecium and androecium. 256.
- Complete flower*. One having gynoecium, androecium, corolla and calyx. 152a.

(Numbers refer to paragraphs.)

- Complete leaf.* One which has blade, petiole and stipules. 118b.
- Compound leaf.* A leaf of which the blade is composed of more than one portion (89); exceptions in 111, 112a.
- Compound pistil.* One which has more than one carpel. 159.
- ConduPLICATE.* Trough-shaped: in cross-section, V-shaped. 59, Fig. 62.
- Cone.* A spicate flower-cluster, in which the flowers or seeds are obscured by scales: strobile: generally applied more particularly to the coniferous gymnosperms. Lix.
- Connate.* Said of two opposite conjoined sessile leaves. 120, Fig. 106.
- Connective.* The stalk or bar connecting the separated lobes of an anther. 165.
- Convolute.* Rolled up, as the corolla in Fig. 275.
- Cordate.* Heart-shaped. 132.
- Corm.* A solid bulb-like tuber. 447.
- Cormel.* A small or secondary corm borne about a large or mother-corm. 449.
- Corolla.* The inner series in a biserial perianth: the petals. 145.
- Corona.* Crown.
- Correlative characters.* Those attributes which have been carried along as secondary or incidental features, and which may have little significance to the present life of the organism. 423b.
- Cortex.* Bark.
- Corymb.* A flat-topped or convex-topped flower-cluster in which the outermost flowers open first. 218.
- Corymbose cyme.* A compound cyme, which appears to be corymbose because the outermost cymules open first. 224.
- Corymbose-cymose.* Determinate inflorescence in which, because of suppression of the interior flowers, the outer flowers open first. 223.
- Co-terminal.* Applied, in this book, to flowers (and fruits) which terminate a growth made the same season. 55.
- Cotyledon.* A seed-leaf: one of the leaves of the embryo. 389a.
- Crenate.* Scalloped. 133.
- Cross.* The offspring of any two flowers which have been cross-fertilized.
- Cross-breed, half-breed, mongrel, variety-hybrid.* A cross between varieties of the same species.
- Cross-pollination.* Transfer of pollen to pistil of another flower. 269c.
- Crossing.* The operation or practice of cross-pollinating.
- Crown.* An outgrowth from the throat of the perianth: corona (213, 250); also the top of a bulb or corm, or of an upright rootstock: also that portion of a plant at the surface of the ground.
- Crown-tuber.* A tuber of which the top is stem and the lower part root. 457.
- Cryptogam.* A flowerless plant: one of the class which does not produce seeds. 427.

(Numbers refer to paragraphs.)

- Culm.* The stem of grasses, sedges, and related plants.
- Cuneate.* Wedge-shaped. 131.
- Cutting.* A severed portion of a plant, set in soil or water, with the intention that it shall grow. 476.
- Cyme.* A flower-cluster of the determinate type,—the central or uppermost flower opening first. 222.
- Cymule.* Secondary cyme: a small cyme in a compound cyme. 224.
- Cypsela.* The akene-like fruit of compositous plants. 293a.
- Decomound.* More than once compound. 97.
- Decurrent.* Said when a sessile leaf-blade is extended down the stem upon which it is attached. 121, Fig. 107.
- Decussate.* Said of four-ranked leaves which are in alternating pairs. 64.
- Dehiscence.* The mode of opening: applied especially to fruits and anthers. 164b.
- Deliquescent.* Said of trees which are diffuse in form of top: the "leader" does not continue. 15.
- Deltoid.* Triangular. 131.
- Dentate.* Toothed: very strongly or coarsely serrate. 133.
- Determinate.* Said of plants in which the upward growth does not take place from the terminal bud. 15, 29.
- Dextrorse.* From left to right. 501a.
- Diadelphous.* Said of stamens which are disposed or united so as to form two groups or companies. 238a.
- Dichogamy.* Term used to express the non-concurrence in maturity of stamens and pistils: the two essential organs maturing at different times in any flower. 150a.
- Diclinous.* Flowers which lack either gynœcium or andrœcium: imperfect. 152a.
- Dicotyledon.* One of the great class of plants characterized by having two (or more) cotyledons. 396.
- Digitate.* Arrangement in which the parts radiate from a common point: palmate. 94.
- Dimerous.* Parts in twos. 246a.
- Dimorphic, dimorphous.* "Two-formed": used to designate the fact of two different relative lengths of stamens and pistils in different flowers of the same kind. 277a.
- Diœious.* Staminate and pistillate flowers borne upon different plants. 192a.
- Discoid.* In compositous flowers used to designate heads which are destitute of rays. 204.
- Dissected.* Deeply cut, as the leaf in Fig. 87.
- Dissepiment.* Partition in a capsule. 312.

(Numbers refer to paragraphs.)

- Distichous.** Two-sided: generally used for branches or flower-clusters, upon which the leaves or flowers are in two opposite longitudinal rows. 67.
- Distinct.** Parts of the flower not joined to other parts in the same series or set. 167.
- Domestication.** The state or condition of being adapted or inured to cultivation, or the act of adapting or inuring to cultivation.
- Dorsal.** Back. 304.
- Drupe.** A stone fruit: having a hard pit and a soft exterior. 300.
- Drupelet.** A very small drupe, especially one which is a part of a head or cluster of fruits. 297.
- Ecology.** The science or study which treats of the relationships of organisms to each other and to their environments. 524.
- Elliptical.** Applied to oblong leaves which gradually taper both ways from the middle. 131.
- Emasculation.** Removal of stamens or anthers. 285.
- Embryo.** The miniature plant in the seed. 406.
- Embryology.** The science which treats of the embryo: in botany, the study of the first or formative stages of any part, either in the seed or the bud.
- Embryo-sac.** A cell in the ovule in which the embryo is developed. 377, 377a.
- Endemic.** Peculiar to a nation, people, or isolated country.
- Endocarp.** The inner layer of a pericarp, especially the hard stone of a drupe. 300.
- Endogen.** Old name for the plants now more generally called monocotyledons; name refers to the manner of lateral growth of the stem. 398.
- Endosperm.** Nutritive matter stored around the embryo in the seed. 410, 410a.
- Entomophilous.** Pollinated by insects. 273a.
- Environment.** The sum of the physical conditions in which an organism lives, often including, also, the condition of struggle for existence. 258c.
- Epicotyl.** Upper internode of the embryo, but not always present: first internode of the plumule. 409a.
- Epigeal.** Said of germination when the cotyledons rise into the air. 401.
- Epigynous.** Parts of the flower borne upon the ovary. 170.
- Epiphyte.** Plant growing upon another plant as a support, but not taking food from the support: air-plant. 517.
- Equitant.** Astride: said of conduplicate leaves of which the edges alternately overlap. 63a.
- Eutropic.** Sinistrorse. 510a.
- Evolution.** The hypothesis which supposes that the forms of life are mutable or changeable, and that one form may, upon occasion, pass into another form.
- Excurrent.** Indeterminate growth: applied to forms of trees in which the "leader" persists. 15.

(Numbers refer to paragraphs.)

- Exocarp.** Outer layer of a pericarp.
- Exogen.** An old name for plants now generally called dicotyledons: name refers to the annual lateral growth of the stem being in rings. 397.
- Extrorse.** Said of anthers with face outwards, or towards the perianth. 163.
- Family.** A more or less natural assemblage or association of plants, thrown together because of a few common bold resemblances. 240a, 559.
- Fasciation.** Abnormal flattening of stems or roots. 71, Fig. 67.
- Fascicle.** A very condensed cymose flower-cluster. 225a.
- Fecundation.** Fertilization.
- Female.** Fertile: pistillate. 152c.
- Fertilization.** Action of the pollen upon the egg-cell of the embryo-sac, resulting in the formation of the embryo: impregnation: fecundation. 269a, 148, 377a, 406.
- Filament.** The stalk of a stamen. 144.
- Filiform.** Thread-like.
- Fimbriate.** Fringed.
- Flora.** The plants of a region (519a): also a book treating of the plants of a region.
- Floret.** An individual flower in a compositous head. 196.
- Follicle.** A simple pod which opens along the ventral suture. 305b.
- Free.** Parts of the flower not joined to parts of another set or series. 167.
- Frond.** An indefinite term, applied to leaves of ferns and palms, and to leaves which have no differentiation of blade and petiole, and which bear the fructification. 424a, 252.
- Fruit.** In botanical writings, the pericarp and its contents, and the parts which are organically united thereto. 291, 291a.
- Frutescent.** Shrubby.
- Fungous.** Fungus-like: of or pertaining to fungi, as a fungous disease.
- Funiculus.** Stalk of a seed. 407.
- Gamopetalous.** Corolla tubular, at least at the base. 210.
- Gamosepalous.** Calyx tubular, at least at the base. 210.
- Generalization.** In natural history writings, used to designate the absence of adaptation to special or particular conditions: not differentiated. 258b.
- Genus.** A group or kind comprising a greater or less number of closely related species. 550.
- Geotropism.** Movement by growth towards the earth. 405a.
- Gill.** A thin and spore-bearing membrane on the pileus of mushroom-like fungi: lamellus. 431.
- Glabrous.** Not pubescent, hairy or downy.
- Gland.** A secreting body. 249a.
- Glomerule.** A small and very condensed cymose flower-cluster. 225a.
- Glume.** A dry or chaff-like bract in the inflorescence of grasses and grass-like plants. 261.

(Numbers refer to paragraphs.)

Glutinous. Sticky.

Graft. A cutting set into a plant: cion. 478.

Gymnosperm. A plant of the class in which the ovules are not in an ovary. 376.

Gynandrous. Gynæcium and andræcium grown together, forming a column. 256.

Gynæcium. Collective name for the pistils. 152d.

Habit. General appearance or looks. 496a.

Habitat. The place in which an organism lives: the habitat of a plant may be a swamp, a lake-shore, or a roadside.

Half-hybrid. The product of a cross between a species and a variety of another species.

Head. A much condensed spike, usually not much higher than broad. 217a, 185a, 225a.

Helicoid cyme. Scorpioid. 225.

Heliotropism. Movement by growth towards the light. 405a.

Herb. A non-woody plant. 493.

Herbarium. A collection of dried plants. 566.

Hermaphrodite. Bi-sexual. 152c.

Heterogonous. Heterostyled. 277a.

Heterostyled. Stamens and pistils of different relative lengths in flowers of the same kind. 277a.

Hexamerous. Parts in sixes. 246a.

Hilum. Scar upon the seed, where it was attached. 407.

Hirsute. Hairy, with rather long loose hairs.

Homology. Similarity of origins. 53b.

Host. Plant (or animal) upon which a parasite or epiphyte lives or grows. 517.

Hybrid. The offspring of plants of different species.

Hybridism, hybridity. The state, quality or condition of being a hybrid.

Hybridization. The state or condition of being hybridized, or the process or act of hybridizing.

Hybridizing. The operation or practice of crossing between species.

Hypha. A thread or stalk of fungi. 436.

Hypocotyl. Lower internode of the embryo: caulicle. 409a.

Hypogæal. Said of germination when the cotyledons remain in the seed or under the ground. 401.

Hypogynous. Said of flowers in which the parts are free 170.

Imbricate. Overlapping.

Imperfect. Lacking either gynæcium or andræcium. 152c.

Impregnation. Fertilization.

Incomplete flower. One from which any of the four series is missing. 152a.

Indehiscent. Not breaking open.

Indeterminate. Said of plants which continue to grow from the terminal bud; such plants have "leaders." 15, 29.

(Numbers refer to paragraphs.)

- Indigenous.* Native: that is, growing in a given region naturally, without the agency, direct or indirect, of man: the term refers to distribution.
- Indusium.* The scale-like covering of the fruit-dot of ferns. 425.
- Inferior.* Said of the ovary when it is not free: below, in position. 169.
- Inflexed.* Bent abruptly forwards or inwards longitudinally: opposite direction to reflexed. 61.
- Inflorescence.* Mode of arrangement of flowers. 225*b*, 182.
- Innate.* Said of an anther attached by its base to the filament. 162*a*.
- Insertion.* Method of attachment. *xx*.
- Inter.* Between.
- Internode.* The stem between the nodes. 46.
- Interrupted leaf.* One which has small leaflets interposed. 101.
- Introrse.* Said of anthers which face inwards, or towards the center of the flower. 163.
- Involucel.* A secondary involucre: a small involucre in a compound involucre flower-cluster. 219*a*.
- Involucre.* A bract, or a whorl of bracts, subtending a flower-cluster or fruit. 174.
- Inovolute.* Rolled inwards above, as the edges of a leaf or petal. 57, Fig. 62.
- Irregular.* Said of flowers in which the parts or lobes of the perianth are of more than one form or shape in the same series. 211*a*.
- Irregularly compound leaf.* One which has leaflets of various and more or less indefinite shapes and sizes. 102.
- Isomorous.* All the parts in each of the four series in the flower of the same number. 211*b*.
- Keel.* The two connivent lower petals of a papilionaceous flower. 237.
- Key-fruit.* A dry indehiscent winged fruit: samara. 319.
- Labiate.* Lipped. 211, Figs. 180, 181.
- Lamellus.* Gill. 431.
- Lanceolate, lance-shaped.* A leaf, or other expanded member, four to six times as long as wide, with the widest part below the middle, and tapering both ways. 128.
- Latent.* Undeveloped: remaining dormant.
- Layer.* A shoot or root, which, while attached to the parent plant, takes root at one or more places, giving rise to new plants there. 459.
- Leaflet.* One integral part of a compound leaf. 93, 98, 99.
- Legume.* A simple pod which opens by both ventral and dorsal sutures. 306.
- Ligneous.* Woody.
- Limb.* The expanded part of a petal or sepal. 210.
- Linear.* Very narrow: several times longer than broad, with the sides parallel. 131.

(Numbers refer to paragraphs.)

- Lobe.** In a leaf-blade, a division not more than half the depth of the blade. 104c.
- Locule.** A compartment of an ovary (156, 156a), or of an anther (161, 161a): cell.
- Locuticidal.** Said of capsules which dehisce at or near the middle of the back of the carpels. 313a.
- Lodicule.** A rudimentary or small body in the flower of grasses, held to represent the perianth. 261.
- Male.** Sterile: staminate. 152c.
- Member.** An external part of an organism, especially one which is not directly concerned in the vital functioning. 118a.
- Micropyle.** The opening in the ovule through which the pollen-tube entered: generally at this place the caulicle of the germinating seed breaks through. 408a.
- Mixed leaf.** A compound leaf which contains divisions of various grades or degrees. 103.
- Monadelphous.** Said of stamens which are united into a single tube or group. 238a.
- Monocotyledon.** One of the class of plants characterized by having only one cotyledon. 396.
- Monœcious.** Staminate and pistillate flowers borne upon the same plant. 192a.
- Monograph.** A systematic or complete account or elaboration of any topic.
- Monopetalous.** Gamopetalous. 210.
- Monstrosity.** An abnormal form or variation. 108a.
- Morphology.** Study of forms, particularly in respect to their origin. 53a.
- Mule.** A sterile (seedless) hybrid.
- Multifid.** Much cleft or cut. 104c.
- Multitermate.** Many, or several times, ternate. 104b.
- Multilocular.** Many-loculed: many-celled. 157a.
- Mycelium.** Vegetative tissue of fungi. 432, 432a.
- Nectary.** A part or place which secretes honey or nectar. 276.
- Neutral flowers.** Those having no essential organs. 202, 202a.
- Node.** A joint on a stem, at which a leaf is normally borne. 46.
- Nut.** In botanical writings, a hard and dry 1-seeded, indehiscent fruit, but in which other ovules have been suppressed. 331a.
- Ob.** Reversed: used only in combinations.
- Ob lanceolate.** Reversed lanceolate: the widest part near the top. 131.
- Oblong.** A flat body twice as long as broad, with sides nearly parallel. 130.
- Obovate.** Reversed ovate: the widest part near the top. 131.
- Obtuse.** Blunt: not acute. 132.
- Ocrea.** Sheath formed of united stipules. 123, Fig. 110.

(Numbers refer to paragraphs.)

- Odd-pinnate.* Having a terminal leaflet: applied to compound pinnate leaves. 100.
- Ecology, ækology.* See Ecology.
- Offset.* A rosette, especially a young rosette which is continuing the propagation of the plant. 443.
- Ontogeny.* Life-history of an organism. 423c.
- Operculum.* Lid of a moss capsule (428b): a lid of any organ, as of a pod or anther.
- Orbicular.* Circular. 131.
- Order.* Family.
- Organ.* A part of a living body directly associated with the vital functioning. 118a.
- Organism.* A body exhibiting life: an animal or plant.
- Oval.* Broadly elliptical. 131.
- Ovary.* That part of a pistil which bears the ovules (or seeds). 143.
- Ovate.* A flat body about twice as long as broad, and tapering from near the base to a very narrow or pointed apex. 129.
- Palea.* Inner glume in the flower of grasses, 261.
- Palmate.* Parts attached to or radiating from a common point: digitate. 94.
- Panicle.* An open or loose flower-cluster of the indeterminate type, but the anthesis often more or less mixed, and which is generally widest towards the base. 221.
- Papilionaceous.* Applied to the typical flowers of the pea family. 237.
- Pappus.* The bristle-like, plume-like, barb-like, or otherwise disguised calyx of compositous flowers. 199.
- Parasite.* A plant which lives and subsists upon another living organism. 435, Lxxix.
- Parietal placenta.* A placenta upon a wall of the locule. 158a.
- Parted.* Said of leaf-blades which are divided about three-fourths the depth of the blade. 104c.
- Pedicel.* A secondary flower-stalk: a stalk of a single flower in a pedunculate cluster: see peduncle. 183, 183a.
- Peduncle.* Flower-stalk: used to designate the single stem of solitary flowers, or of flowers in a simple or unbranched sessile cluster, and also for the common stalk of a cluster: see pedicel. 183, 183a.
- Peltate.* Attached to the expanded surface, rather than to the edge or margin: said chiefly of leaves in which the petiole is attached inside or beyond the edge. 125, Fig. 111.
- Pentamerous.* Parts in fives. 246a.
- Pepo.* Fruit of the kind represented by the pumpkin, squash, melon and cucumber. 356.
- Perennial.* A plant which lives more than two years. 488.

(Numbers refer to paragraphs.)

- Perfect.* Flowers having both gynoecium and androecium.
- Perfoliate.* Leaf-blade enclosing the stem. 121, Fig. 109.
- Perianth.* The floral envelopes: the "leaves of the flower." 145.
- Pericarp.* The ripened ovary: seed-vessel. 291.
- Perigynium.* The perianth-like body enclosing the akene in the carices. 267.
- Perigynous.* Said of flowers in which the gynoecium sits in the calyx-tube, upon which tube other parts of the flower are borne. 170.
- Peristome.* The margin of fringe or teeth about the orifice of the capsule o. mosses. 428b.
- Petal.* One of the parts of a corolla: one of the inner (and usually colored) members of a biserial perianth. 145.
- Petaloid.* Resembling a petal. 255.
- Petiole.* The stalk or stem of a leaf. 87.
- Petiolule.* The stalk of a leaflet. 90.
- Phanerogam.* One of the class of flowering or seed-bearing plants. 427.
- Phenology.* The study of the relationship of local climate to the annual periods of animals and plants. 526, 526a.
- Plurifoliolate.* With many leaflets. 104a.
- Phyllodium.* A petiole which resembles a leaf-blade, and performs the functions of foliage. 115a.
- Phyllotaxy.* The arrangement of leaves, branches, or flowers upon the stem. 70.
- Phylogeny.* Genealogy: natural history of a race. 423c.
- Phyton.* As conceived by the writer, the smallest part of root, stem or leaf, which, when severed, may grow into a new plant: a potential cutting. 479.
- Pileus.* The cap or top of mushroom-like fungi. 429.
- Pinna.* A primary leaflet in pinnately compound leaves. 99.
- Pinnate.* Parts arranged on opposite sides of a rachis. 94.
- Pinnatifid.* Pinnately lobed. 104c.
- Pinnatisect.* Said of pinnate leaves divided into segments. 104c.
- Pinnule.* Secondary leaflet of a fern frond (426a): a secondary leaflet in pinnately compound leaves. 99.
- Pistil.* That part of the flower which bears the ovules: it ripens into a fruit. 142.
- Pistillate.* Said of flowers which have gynoecium, but no androecium. 152c.
- Placenta.* Place of attachment of ovules in the ovary. 158.
- Plaited.* Folded together sidewise into parallel folds: plicate. 60, Fig. 62.
- Plane.* Flat: said of leaves and other expanded bodies which do not curl or twist.
- Plicate.* Plaited: folded together sidewise into parallel folds. 60, Fig. 62.
- Plumose.* Feather-like.
- Plumule.* The bud of the embryo, usually lying between the cotyledons. 389b.

(Numbers refer to paragraphs.)

- Plur-annual.** A plant which is an annual only because it is killed by the closing of the growing season. 489a.
- Pod.** A dry, dehiscent pericarp. 305a.
- Pollen.** The contents of the anther, and which fecundates the ovules when applied to the pistil: it is usually in the form of grains. 144, 147.
- Pollination.** The act or fact of conveying pollen from anther to stigma. 148, 269d.
- Pollinium.** A mass of coherent pollen, occupying nearly or quite the entire locule. 279a.
- Poly.** Many or numerous: used only in combinations.
- Polygamous.** Hermaphrodite and diclinous flowers variously mixed upon the plant. 193.
- Polypetalous.** Parts of the corolla distinct. 209.
- Polysepalous.** Parts of the calyx distinct. 210.
- Pome.** Fruit of the kind represented by the apple, pear, quince and hawthorn. 348.
- Progressive inflorescence.** An indeterminate inflorescence in which the whorls are widely separated. 220.
- Prostrate.** Lying upon the ground. 406.
- Proterandrous.** Stamens maturing before the pistils in the same flower. 190a.
- Proterogynous.** Pistils maturing before the stamens in the same flower. 190a.
- Pseud-annual.** Plants which are practically annuals, but which carry themselves over to the next season by means of bulbs, corms, and the like, rather than by seeds. 490a.
- Pteridophyte.** Term used to designate the cryptogamous plants which have distinct vascular bundles or woody fiber: includes ferns, equisetums, isoetes, club-mosses, etc. 437a.
- Pubescent.** Covered with fine short hairs.
- Putamen.** The pit or stone of a drupe (300); also the shell of a nut.
- Pyxis.** A pod which opens on or near the top by a lid or cover. 308.
- Quadrifid.** With four clefts or parts. 104c.
- Quadrifoliate.** With four leaflets. 104a.
- Quadrilocular.** 4-loculed: 4-celled. 157a.
- Quadriserial.** A term proposed in this book to designate flowers having all of the four series,—gynæcium, andrœcium, corolla, calyx. 152a.
- Quinefoliolate.** With five leaflets. 104a.
- Quinquelocular.** 5-loculed: 5-celled. 157a.
- Raceme.** A simple open inflorescence, in which the flowers are on pedicels and the lowest ones opening first. 216.
- Rachis.** The axis of a compound leaf or of a dense elongated flower-cluster (as of a spike). (94): mid-rib of a compound leaf (88) or frond (426a).
- Radicle.** Old name for the caulicle. 409a.

(Numbers refer to paragraphs.)

- Ray.** Among other uses, used to designate the much-prolonged one-sided limb of the corolla in compositous flowers. 203.
- Receptacle.** The expanded end of the stem upon which the flower is borne: torus: flower-seat. 166, 201, 207.
- Reflexed.** Bent abruptly backwards or outwards longitudinally: opposite direction to inflexed. 61.
- Regular.** Said of flowers in which the parts or lobes of the perianth are alike in each series. 211a.
- Reinforced.** In this book, used to designate flowers and fruits with which various petal-like or calyx-like bracts or leaves are organically associated. xxviii., llii., liv.
- Reniform.** Kidney-shaped. 132.
- Repend.** Slightly wavy, as the margin of a leaf. 133.
- Retuse.** Indented at the end. 132.
- Revolute.** Rolled under at the edges. 58, Fig. 62.
- Rhizome.** Rootstock. 453a.
- Root-hair.** The minute projection upon roots, through which the most active absorption takes place. 404.
- Rootstock.** An underground stem, by means of which the plant propagates or carries itself over an unpropitious season: rhizome. 453a.
- Rosette.** A much-shortened stem bearing a dense cluster of leaves, especially if it is formed upon the ground and assists in the propagation of the plant: see offset. 443.
- Rotate.** Wheel-shaped. 211a, Fig. 178.
- Runner.** A special kind of prostrate layer, taking root and forming new plants as it grows. 460.
- Sagittate.** Arrow-shaped. 132.
- Salver-shaped.** Limb of perianth standing at right angles to a narrow tube or base. 211a, Fig. 177.
- Samara.** A dry and indehiscent winged fruit: key-fruit. 319.
- Saprophyte.** A plant which lives upon dead or decaying organic matter. 435, lxxix.
- Sarcocarp.** The fleshy part of a drupe: soft exocarp. 300.
- Scabrous.** Roughened: covered with rough elevations.
- Scape.** A peduncle which arises from the ground, is simple, or nearly so, not jointed, and destitute of foliage, 214a.
- Scarious.** Dry: not fresh and soft. 105.
- Scorpioid cyme.** A one-sided coiled inflorescence, with the oldest flower at the base (but this flower conceived to represent the termination of the axis). 225.
- Seed.** The direct product of the fertilization of the flower, a body which con-

(Numbers refer to paragraphs.)

- tains an embryo plant and the office of which is to perpetuate the kind: the ripened ovule. 411, 291.
- Seedling*. A plant growing directly from seed, without the intervention of grafts, layers or cuttings.
- Segment*. In a leaf-blade, a division extending practically to the midrib. 104c.
- Self-fertilization*. Action of pollen upon a pistil of the same flower: close-fertilization. 269b.
- Sepal*. One of the parts of a calyx: an outer (and usually green) member of a biserial perianth. 146.
- Sepaloid*. Resembling a sepal.
- Septicidal*. Said of capsules which dehisce into parts representing the component carpels. 313a.
- Septifragal*. Said of capsules which dehisce septicidally and the outer sides or walls of the carpels break away from the dissepiments. 314.
- Serrate*. Saw-toothed. 133.
- Sessile*. Without a stalk or stem. 88a.
- Sheath*. A hollow or tubular part, as of a leaf, enclosing a stem or root. 122.
- Shrub*. Ligneous perennial plant with no trunk: bush. 495.
- Silicle*. A short and very broad pod of the mustard family. 307a.
- Silique*. A long pod of the mustard family. 307a.
- Sinistorse*. From right to left. 501a.
- Sinuate*. Strongly wavy. 133.
- Sinus*. The recess or notch in the base of a leaf. 132.
- Smooth*. Not scabrous.
- Sorus*. A collection or colony of sporangia in ferns: fruit-dot. 425.
- Spadix*. A spike enclosed or subtended by a spathe: the axis usually more or less fleshy. 191.
- Spathe*. A 1-leaved or 2-leaved involucre enclosing a flower or flower-cluster: 191, 213.
- Spatulate*. Oblong in general outline, but the upper end broadened. 131.
- Spawn*. Subterranean mycelium of mushroom-like fungi (432, 432a): also cormels (449).
- Specialization*. In natural history writings, used to designate modification of structure or habits enabling an organism to live in particular conditions or to perform particular functions. 258a.
- Species*. The unit in classification. 548.
- Spermatophyte*. One of the class of seed-bearing plants. 437a.
- Spike*. A simple and dense elongated flower-cluster in which the individual flowers are sessile, or very nearly so, and the lowest flowers open first. 217, 185a.
- Spikelet*. The ultimate flower-cluster in the inflorescence of grasses. 262.
- Sporangium*. Case or body containing the spores. 424.

(Numbers refer to paragraphs.)

- Spore*. The reproductive body of cryptogams, containing no embryo, and not always the direct result of a sexual process: analogous to a seed. 428.
- Stamen*. That part of the flower which bears the pollen. 144.
- Staminate*. Said of flowers which have androecium but no gynoecium. 152c.
- Staminoid*. Resembling a stamen.
- Staminodium*. A sterile, or antherless, stamen: a body standing in the place of a stamen and presumably representing a stamen. 230a.
- Standard*. The large upper expanded petal of a papilionaceous flower: vexillum: banner. 237.
- Stem*. The ascending or aerial axis of a plant, in distinction to the root, leaves, etc.: trunk.
- Stigma*. The expanded end of a pistil, upon which the pollen falls and germinates. 143.
- Stipe*. The stem of a fern frond (424a), or of a mushroom (429).
- Stipel*. Secondary stipules: appendages of leaflets. 91.
- Stipule*. An appendage of a leaf or leaf-blade at the base of the blade or on the petiole. 87.
- Stolon*. A layer which bends over, or is not prostrate, taking root at the tip, or near it. 461.
- Strict*. Straight: said of very erect-growing plants, particularly if the head is narrow and the growth is indeterminate.
- Strobile*. Cone.
- Style*. The more or less elongated portion which, in many pistils, joins the ovary and stigma. 143.
- Subtend*. To stand under or at the side of, forming an axil, as a scale subtending a flower. Figs. 173B, 222.
- Sucker*. A sprout or shoot arising from an underground root or stem (463): also, an adventitious shoot in the top of a plant, especially a vigorous shoot.
- Superior*. Said of the ovary when it is free: above, in position. 169.
- Suture*. Junction or place of union. 305a.
- Syconium*. Fruit of the kind represented by the fig. 369.
- Symmetrical*. Parts in each of the four series in the flower of the same number, or in multiples of the lowest number. 211b.
- Syn*. United or simultaneous; used only in combinations.
- Synanthous*. Stamens and pistils maturing simultaneously in any flower. 193.
- Syncarpous*. Carpels, or simple pistils, united. 305.
- Syngenesious*. In a ring: applied to the anthers of compositous flowers, because they are united in a ring around the styles. 200.
- Tap-root*. A central or leading root, running deep into the soil. 499.
- Teratology*. The science or study of monstrosities. 228a.
- Terete*. Cylindrical.

(Numbers refer to paragraphs.)

- Terminology.** The subject or study of terms or names.
- Ternate.** Parts in threes: said chiefly of leaves. 96.
- Tetramerous.** Parts in fours. 246a.
- Thallophyte.** Name applied to the low orders of flowerless plants, designating those which, as a class, have no proper differentiation of axis (and therefore no detaching leaves), or of vascular tissue, includes algæ, lichens and fungi. 437a.
- Thyrse.** A dense or contracted panicle. 226.
- Torus.** Receptacle. 166.
- Tree.** A ligneous perennial plant with a central shaft or trunk, and a more or less elevated head. 494.
- Trifid.** With three clefts or parts. 104c.
- Trifoliolate.** With three leaflets. 104a.
- Trilocular.** 3-loculed: 3-celled. 157a.
- Trimerous.** Parts in threes. 246a.
- Trimorphic, trimorphous.** "Three-formed"; used to designate the fact of three different relative lengths of stamens and pistils in different flowers of the same kind. 277a.
- Tripalmate.** Thrice palmate. 104b.
- Tripinnate.** Thrice pinnate. 104b.
- Trisect.** With three segments. 104c.
- Triserial.** A term proposed in this book to designate flowers which contain all the series except calyx,—gynœcium, andrœcium, corolla. 152a.
- Triternate.** Thrice ternate. 104b.
- Truncate.** The end squared, as if cut off. 132.
- Tuber.** In this book, a prominently thickened and homogeneous, and usually subterranean, portion of a root or stem which does not increase itself and the plant by means of direct offshoots or accessions. 456b.
- Tubercle.** Crown-tuber. 457.
- Tunicated.** Covered with enclosing or concentric plates. 441.
- Umbel.** A corymbose flower-cluster in which the pedicels start from the same point, or approximately the same point. 219.
- Umbellet.** A secondary umbel: a small umbel in a compound umbel. 219a.
- Unifoliolate.** With one leaflet. 104a.
- Unilocular.** 1-loculed: 1-celled. 157a.
- Uniserial.** A term proposed in this book to designate flowers which have only the gynœcium. 152a.
- Unisexual.** Of one sex: containing only stamens or pistils. 152c.
- Vaginate.** Sheathing. 122.
- Valvate.** Edges meeting (63a): also opening by lids or doors or valves.
- Valve.** One of the parts or pieces of a dehiscent pod.

(Numbers refer to paragraphs.)

Variety. A form, which, in the judgment of any writer, is considered to be subordinate to the species in classificatory importance. 552.

Veil. The membrane joining the edge of the pileus to the stipe, in mushroom-like plants. 431.

Venation. Veining. Page 96.

Ventral. Front. 304.

Vernation. The folding of the leaves in the bud. 63.

Versatile. Said of an anther which is attached near its middle. 162a.

Verticillate. Leaves, or other members, which are more than one pair at a node: whorled. 65.

Vezillum. Standard.

Volva. A sheath about the base of the stipe in certain mushroom-like plants. 433.

Whorled. Verticillate: more than one pair (as of leaves) at a node. 65.

INDEX

(Numbers refer to pages.)

- | | |
|---|---|
| <p> Abutilon flower, 209.
 Acacia leaves, 91, 105, 106; movement in, 402.
 Accessory buds, 39.
 Acer nigrum, 429; saccharinum, 429.
 Achenium, 251.
 Achlamydeous, 139.
 Acorns, 281, 284.
 Acquired character, 341.
 Acuminate, 118.
 Acute leaf, 118.
 Adaptation, 287, 340.
 Adder's-tongue, 356.
 Adlumia flower, 214.
 Adnate anther, 147.
 Adventitious growths, 205.
 Æstivation, 61.
 Agrimony, fruit, 279; rootstock, 360.
 Ailanthus, phyllotaxy, 68.
 Air-plant, 410.
 Akene, 251.
 Algæ, 352.
 Alleghany vine, 214.
 Allen, book by, 447.
 Almond, double, 204.
 Almond, fruit, 277.
 Alyssum, 222; fruit, 262.
 Amaranthus albus, 337.
 Amelioration, 418.
 Ament, 156.
 Ampelopsis, 400. </p> | <p> Amphicarpæa, 244.
 Amplexicaul leaf, 110.
 Anacharis, 357.
 Analogy, 53.
 Andræcium, 139.
 Androgynous, 166.
 Anemone, flower of, 153.
 Anemophilous, 236.
 Angiosperms, 309.
 Annual, 386.
 Annulus, 347.
 Anther, 134.
 Anthesis, 196.
 Anthotaxy, 196.
 Anthuriums, 169.
 Antitropic, 398.
 Apetalous, 139.
 Apetaly, 215.
 Apgar, book by, 289.
 Apical dehiscence, 263.
 Apios, leaves, 100.
 Apocarpous, 261.
 Apple, fertilization, 312; flower, 140; flower-cluster, 48, 249, 382; form of top, 14; fruit, 256, 289; healing of wounds, 72; inflorescence, 193; leaves, 80, 110, 113; phenology, 417; phyllotaxy, 67; receptacle, 151; seed of, 335; stamen, 150; twigs, 1 et seq., 25 et seq.,* 43, 44, 57, 73.
 Apple-scab, 77, 352. </p> |
|---|---|

* *Et sequentes* : the pages which immediately follow.

(Numbers refer to pages.)

- Apricot, branch, 48; flower, 188; fruit, 256, 257.
 Aquilegia, double, 206.
 Arborvitæ, leaves, 125.
 Aristolochia, 210.
 Aristolochiaceæ, 212.
 Arrangement of flowers, 188, 193.
 Arrow-leaf, 191.
 Arthur, book by, 424.
 Arums, classification, 327.
 Arundo, 41.
 Asarum, 212.
 Asclepias, pollination, 243.
 Asepalous, 139.
 Ash, fruit, 272.
 Asparagus, flower, 186; leaves, 103.
 Aspidium, 342.
 Assimilation, 423.
 Aster, floret of, 182; leaf-scars, 42.
 Asters, associates of, 412.
 Atkinson, writings of, 350.
 Attachment of leaf, 110.
 Auriculate leaf, 111, 119.
 Axil, 1.
 Axile placenta, 143.
 Axis, deflected, 7.
 Azalea, anther, 148; bud, 52; fruit, 264.

 Bacteria, 352.
 Bags for flowers, 248.
 Bailey, books by, 125, 250, 282, 302, 314, 380, 385, 416, 421, 442, 452.
 Bailey, W. W., books by, 442, 443.
 Baldwin, book by, 443.
 Balloon-vine, 268.
 Balm of Gilead, twig, 38.
 Balsam, double, 206; fruit, 267; seed of, 335.
 Bamboo, 230.
 Banana, seedless, 376.
 Bananas, classification, 327.
 Baneberry, fruit, 277.
 Banner, 207.
 Barberries, shoots of, 11, 36.
 Barberry, anther of, 149; leaf, 113; leaves, 102, 103.
 Bark-bound, 71.
 Bark, expansion of, 69.
 Barley, 230.
 Barometer, 414.
 Basin, 294.
 Basswood, inflorescence, 193; phenology, 417; phyllotaxy, 65; stature, 389.
 Basswoods, associates of, 413.
 Real, book by, 230.
 Bean, climbing, 402; flower, 207; fruit, 261, 268; germination of, 327-331; jack, 268; leaf, 85, 99; movement in, 402; tuberos, 364.
 Bedstraw, 64.
 Beech, catkins, 161.
 Beech-drop, 409.
 Beeches, associates of, 413; leaf-casting, 43.
 Beechnut, 281.
 Bees, 234, 237.
 Beet, evolution of, 388; roots of, 393; tubers, 363.
 Beggars, 406.
 Beggar's-ticks, 338.
 Begonia, adventitious buds, 292, 376; cutting, 378; flower, 152.
 Begonias, 222.
 Bell-jar, 380.
 Bell-shaped corolla, 185.
 Bentham & Hooker, book by, 434.
 Bergen, book by, 447.
 Berries, 273.
 Bi-compound, 91, 95.
 Biennial, 386.
 Bifoliate, 95.
 Bilocular, 142.
 Binomial nomenclature, 428.

(Numbers refer to pages.)

- Bipalmate, 95.
 Biplinnate, 95.
 Birch, catkins of, 157, ; leaves, 121.
 Birds, carry seeds, 338; pollination by, 245.
 Birthwort family, 212.
 Biserial flower, 139.
 Biternate, 89, 95.
 Blackberries, dispersion, 338; habits, 390; fruit, 255, 274, 304; inflorescence, 197; leaf, 78; phenology, 417; scrambling, 401; shoots, 55.
 Blackbirds, 171.
 Black currant, twigs, 365, 181.
 Black-rot, 352.
 Black walnut, fruit, 285; twigs, 39.
 Blade of leaf, 80.
 Bleeding-heart, 90; duration of, 386 388; flower, 214.
 Blight, 352.
 Blood-root, rhizome, 362.
 Blooming, dates of, 414.
 Blue-beech, catkin, 158.
 Bluebells, renewing, 388.
 Blue cohosh, 278.
 Blue-flag, flower, 152, 187; fruit, 265; rhizome, 362.
 Boards, knots in, 23.
 Boll of cotton, 265.
 Boneset, 183.
 Borage, inflorescence, 195.
 Borers, 21.
 Boston ivy, 87, 400.
 Botanizing, 440, 443.
 Bouvardias, 222.
 Box-elder, fruit, 271.
 Boxes for seeds, 330.
 Books, 446.
 Brace roots, 374.
 Bracts, 97.
 Branch, 3.
 Bread mold, 351.
 Breeding of plants, 418.
 Brick or spawn, 350.
 Britton, book by, 443.
 Brugmansia, double, 206; fruit, 275.
 Bryophyllum, 375.
 Bryophytes, 352.
 Buckwheat, 240; inflorescence, 193; leaf, 112; seed, 334.
 Bud-scales, 50.
 Buds and bulbs, 353, 357.
 Bulblots, 353.
 Bulbous plants, 327, 353.
 Bulbs, 353; perpetuation by, 387; scales growing, 375.
 Bulbs vs. buds, 357.
 Bullrush, 226.
 Bull-thistle, duration of, 386.
 Bumble-bees, 238.
 Burdock, 182, 183; dissemination, 338; fruit, 280, 305.
 Bushes, 10, 390.
 Butcher's broom, 104.
 Buttercup, flower, 152, 238. [39.
 Butternut, fruit, 285; leaf, 92; twigs, Buttons of mushroom, 349.
 Buttonwood, 40, 161.
 Cabbage, head, 356; fruit, 262.
 Cacti, 364; classification, 326; movement in, 406.
 Calanthe, 226.
 Calcium, 422.
 California poppy, 403.
 Calla, flower, 168.
 Calliopsis, 179.
 Calyptra, 347.
 Calyptrate buds, 40.
 Calyx, 135.
 Campanulate corolla, 185.
 Canada thistle, leaf, 86; spread of, 361, 367.
 Canes, 390.

(Numbers refer to pages.)

- Canna, flower, 201; fruit, 265; rhizome, 360; seed of, 335.
 Cannas, classification, 327; leaf-scars, 42.
 Capitulum, 165, 190, 196.
 Cap of mushroom, 347.
 Capsicum, fruit, 276.
 Capsule, 263.
 Caraway, inflorescence, 190.
 Carbon dioxid, 422.
 Carding factories, 337.
 Cardiospermum, 268.
 Carex (carices), 164, 230; layer of, 367.
 Carnation, double, 203, 206; flower, 152; placenta, 143; stamen, 150.
 Carnations, 222.
 Carrot, duration of, 387; inflorescence, 190; roots of, 393; tubers, 364.
 Carya alba, 44; porcina, 44.
 Caryopsis, 253.
 Cassabanana, 399.
 Castilleja, 156.
 Castor bean, duration of, 386; flower, 219; fruit, 264; seed of, 335.
 Catalpa flower, 184.
 Catchfly, placenta, 143.
 Catkin, 156.
 Catnip, flower, 140, 184, 253; leaf-scars, 42.
 Cattle and plants, 383.
 Cattleya, 226.
 Caudicle, 243.
 Caulicle, 332.
 Caulophyllum, fruit, 278.
 Cavity, 294.
 Cayenne pepper, 276.
 Cedar, 310; leaves, 125.
 Celery, blanching; 423; inflorescence, 190.
 Cell of anther, 146.
 Cell of ovary, 141.
 Centripetal inflorescence, 193.
 Cereal grains, leaf-scars, 42.
 Cereals, 230; classification, 327; endosperm, 334.
 Chapman, book by, 443.
 Checking growth, 6, 205.
 Cherries, dispersion, 338.
 Cherry, black, 18; flower, 152; fruit, 256, 258; morello, 19; phenology, 417; stature, 388, 389; suckering, 370; sweet, 19; vernalion, 58.
 Cheese mold, 351.
 Chestnut, family, 284; flowers, 161; fruit, 286; leaf, 117; phenology, 417.
 Chicory, 183.
 Chickweed, placenta, 143.
 Chili pepper, 276.
 Chlorophyll, 350, 407 et seq., 423.
 Chrysanthemum, florets, 183; leaves, 128.
 Chrysanthemums, 222; renewing, 388.
 Cinerarias, 222.
 Circulation in plants, 424.
 Circumcissile, 263.
 Cladophyllum, 105.
 Clarke, essay by, 282.
 Claspig leaf, 110.
 Classification, 432, 447.
 Claw, 134.
 Clearings, 383.
 Cleistogamous, 244.
 Clematis, climbing of, 400; fruit, 276.
 Climate, study of, 415.
 Climbing plants, 396.
 Close-fertilization, 234.
 Clot-bur, 338.
 Clover, dodder on, 407; flower, 207; four-leaved, 130; fruit, 269; movement in, 402; roots of, 393.
 Club-moss, 346, 352.
 Cobia leaf, 97.

(Numbers refer to pages.)

- Cockle-bur, 280.
 Cockle, dispersion, 338.
 Coconut, dispersion, 339; fertiliza-
 tion, 313; fruit, 282; germination,
 332, 335; milk in, 334.
 Cohosh, anther of, 149; fruit, 277,
 278.
 Collateral buds, 40.
 Collecting, 440, 443.
 Collective fruits, 305.
 Columbine, double, 206; flower, 237;
 fruit, 259, 263, 270, 276.
 Columbines, renewing, 388.
 Column of orchids, 223.
 Comfrey, inflorescence, 195.
 Complete flower, 138; leaf, 109.
 Compositæ, 209.
 Composites, classification, 326; inflo-
 rescence, 197.
 Compositous flowers, 176, 177.
 Compound leaf, 86; pistil, 144; pod,
 263.
 Conduplicate, 58.
 Cone family, 209, 310.
 Cones, discussion of, 306; phyllotaxy,
 68; pollination of, 236.
 Coniferæ, 209, 310.
 Connective, 149.
 Connivent stamens, 183.
 Cordate, 118.
 Coreopsis, 179.
 Coriander, inflorescence, 190.
 Corm, 358.
 Cormel, 359.
 Corms, perpetuation by, 387.
 Corn and pumpkins, 384.
 Corn, 230; ear of, 166; flower, 228;
 leaf-scars, 42; movement in, 403;
 phyllotaxy, 65; pollination of, 236;
 roots of, 374; study of, 166; suck-
 ering, 370; (maize) dispersion, 338;
 (maize) seed of, 335.
 Corn, cockle fruit, 278; placenta,
 143, 145.
 Cornus florida, 417.
 Corolla, 134.
 Corpse-plant, 408.
 Correlative characters, 341.
 Corymb, 190.
 Corymbose-cymose, 194.
 Cosmos, 179.
 Co-terminal buds, 55, 162.
 Cotton, duration of, 386; flower, 209;
 fruit, 265.
 Cottonwood, sex of, 163.
 Cotyledons, 320.
 Coulter, books by, 443.
 Cows, carry seeds, 334.
 Crab apple, 28, 44.
 Grape myrtle, 212.
 Crenate, 119.
 Crocus, 359; duration of, 386; flower,
 187; phenology, 417; stamen, 150.
 Cross-fertilization, 234, 239.
 Crossing, 246.
 Crowfoot, family, 252, 270; flower, 238.
 Cruciferæ, 209.
 Cryptogams, 346.
 Cucumber, climbing of, 398, 402;
 flowers, 164; fruit, 295; seedless,
 314; seed of, 335.
 Cucurbitacæ, 209, 298.
 Cultivating plants, 448.
 Cultivation, 300.
 Cuneate, 118.
 Cupuliferæ, 284.
 Currant, flower, 145, 152; fruit, 274;
 Indian, 381; phenology, 417; ra-
 ceme, 189; twigs, 36, 37, 43, 51, 81;
 habit, 390.
 Cushaw pumpkin, 299.
 Cut leaves, 119.
 Cutting-bed, 380.
 Cuttings, 374.

(Numbers refer to pages.)

- Cycloloma, 337.
 Cyclone plant, 337.
 Cyme, 193.
 Cymule, 194.
 Cypress, 310.
 Cypripedium, 222, 226.
 Cypsela, 253.

 Dahlia, amelioration of, 420; florets, 183; leaf, 94, 110; leaf-scars, 40; tubers, 363.
 Daisies, 183.
 Daisy, ox-eye, 177; Paris, leaves of, 129.
 Dalibarda, 243.
 Dana, book by, 443, book by, 447.
 Dandelion, 171 et seq.; dispersion, 337; fruit, 253; phenology, 416, 417; associates of 411, 413.
 Darkness, roots towards, 405.
 Darwin, books by. 99, 240, 242, 246, 402, 406, 447; mentioned, 235, 237, 384, 403.
 Darwinism, 418.
 Dates, 414.
 Datura, double, 206; fruit, 265, 275.
 Daubentonia, 269.
 Day-lily fruit, 265; rhizome, 362.
 DeCandolle 434; book by, 447.
 Decom-pound, 91, 95.
 Decurrent leaf, 110.
 Decussate, 64.
 Definitions, 95.
 Dehiscence, 149.
 Deliquescent tops, 14.
 Deltoid, 118.
 Dentate, 119.
 Determinate growth, 14, 189.
 Dewberry habit, 390; leaf, 78; preparation 368.
 Dextrorse, 398.
 Diadelphous, 208.
 Diagrams of leaves, 120, 344.
 Dicentra, leaf, 89.
 Dichogamy, 137 224.
 Dielinous, 139 flowers, 156, 163, 168,
 Dicotyledons, 325.
 Digitate, 87.
 Dilated petiole, 110.
 Dill inflorescence, 190.
 Dimerous, 2 4.
 Dimorphic, 240.
 Dioecious, 170.
 Disc flowers, 179.
 Discoid, 179.
 Discs on tendrils, 400.
 Disguises of leaves, 96.
 Dispersion of seeds, 336.
 Dissemination of seeds, 336.
 Distichous, 66.
 Divergence of character, 384.
 Dock leaf, 13.
 Docks, associates of, 413; in orchards, 384.
 Dodder, 407.
 Dodge, book by, 346.
 Dog's-tooth violet, 356.
 Dog-wood, flowering, 155, 163; phenology, 417; twigs, 9.
 Domestic plants, 418.
 Dormant buds, 3.
 Dorsal, 260.
 Double flowers, 203.
 Drupe, 255.
 Drupelet, 255.
 Drying plants, 441.
 Dutchman's breeches, 214.
 Dutchman's pipe, 210.
 Duckmeat, 219; frond of, 342; classification, 327.
 Duration of plants, 386.

 Ear of corn, 166.
 Earth, roots towards, 330, 405.

(Numbers refer to pages)

- Easter lily, 353.
 Eaton, book by, 346.
 Ecology, 413.
 Egg-cell, 311, 331.
 Egg-plant, flower, 183; fruit, 275; seedless, 314.
 Elder, buds, 10, 11; inflorescence, 195, 197, 198; phenology, 417; suckering, 370.
 Elliot, Miss, quoted 449.
 Elliptical, 118.
 Elm, bark, 70; form of top, 14; fruit, 272; phyllotaxy, 65.
 Emasculation, 247.
 Embryo, 332.
 Embryo-sac, 311, 331.
 Endocarp, 257.
 Endogens, 326.
 Endosperm, 334.
 Engler & Prantl, book by, 435.
 Entire leaf, 119.
 Entomophilous, 236.
 Environment, 226.
 Epicotyl, 334.
 Epigæa, 240, 390; phenology, 417.
 Epigeal, 328.
 Epigynous, 152.
 Epiphytes, 223, 406.
 Equisetum, 346, 352.
 Erigenia, 4 7
 Eschscholtzia, 403.
 Essential organs, 136.
 Euphorbia flower, 218.
 Eutropic, 398.
 Evolution, 448.
 Excurrent tops, 14.
 Exocarp, 257.
 Exogens, 325.
 Explosive fruits, 339.
 Extrorse anther, 148.
 Falconer, book by, 350.
 False spikenard, 360.
 Family, 209.
 Fasciation, 68, 69.
 Fascicle, 196
 Female flowers, 139.
 Fence-row, flora of, 411.
 Fern, stag's-horn, 410; vernation, 60.
 Ferns, 342, 352.
 Fertile flowers, 139.
 Fertilization, 135, 234; of strawberry, 254, 311.
 Feverfew, leaves, 128.
 Fig, fruit, 304.
 Filament, 134.
 Filberts, 281, 284.
 Fire and plants, 383.
 Fire, scorching of cones, 309.
 Fir leaves, 107 125.
 Firs, catkins, 306; phyllotaxy, 68.
 Flax, 240; dodder on, 407.
 Fleeces, seeds in, 337.
 Flora, 411.
 Floral envelope, 134.
 Floras of given regions, 442.
 Flower-pot, 331.
 Flower-seat, 50.
 Flower, what is a ? 131.
 Fly-catchers, 405.
 Foliation, 61.
 Follicle, 261.
 Food of plants, 421.
 Forcing fruits, 314.
 Forest, 336, 384.
 Forest trees, 289.
 Forget-me-not, inflorescence, 195.
 Forms of leaves, 115.
 Forsythia, leaves, 87; suspensa, 87.
 Foxglove, flower, 183.
 Frames for seeds and plants, 330, 380.
 Free and distinct, 150.
 Freexias, 222.
 Frond, 220, 342.

(Numbers refer to pages.)

- Fruit, 252; bud, 5; dot, 343; spur, 25.
 Frutescent, 393.
 Fuchsia, double, 206; flower, 152; stamen, 150.
 Fuchsias, 222.
 Fuller's teasel, 181.
 Full flowers, 203.
 Fungi, 351, 352; in wood, 21.
 Funiculus, 332.
 Funkia, fruit, 265.

 Galium, 64; scrambling, 401.
 Galls on oak, 285.
 Gamopetalous, 184.
 Gamopetalý, 215.
 Gamosepalous, 184.
 Gardener and plant-breeding, 418.
 Gases, 422.
 Gaye, book by, 413.
 Geddes, book by, 99, 406.
 Generalization, 225.
 Genealogy, 341.
 Geotropism, 330.
 Geranium, cutting, 378, 380; double, 204, 206; stamen, 150.
 Geraniums, 222.
 Germination, 316 et seq.; of pollen 311.
 Gherkin, flowers, 164; fruit, 294.
 Gibson, book by, 350.
 Gills, 348.
 Ginger, root, 362; wild, 212.
 Ginkgo, 310.
 Girdling, 424.
 Gladiolus, corm, 358; flower, 187.
 Gland, 216.
 Glomerule, 196.
 Glossary, 455.
 Glue for mounting plants, 442.
 Glumes, 227.
 Goethe, views of, 206.
 Goff, book by, 447.
 Golden-rod, duration of, 386; florets, 183; leaf-scars, 42.
 Goodale, book by, 447.
 Gooseberry, habit, 390; fruit, 274; twigs, 35, 43.
 Gourd, family, 209, 295; flowers, 164; fruit, 295.
 Grafts, 374.
 Grains, leaf-scars, 42.
 Graminæ, 209, 230.
 Grape, canes, 390; description of, 428; flowers, 215; fruit, 273; growth of, 14; inflorescence, 197; leaves, 84, 113, 123; phenology, 417; shoots, 55; tendrils, 401.
 Grasses, classification, 327; leaf-scars, 42; movement in, 403.
 Grass, family, 209, 230; flower, 227; phyllotaxy, 65; seeds and weeds, 338.
 Greenbrier, 41, 42; leaves, 122, 124.
 Greene, book by, 443.
 Greenhouse, miniature, 380.
 Ground-cherry, fruit, 279.
 Ground-nut, leaves, 100.
 Growing of plants, 448.
 Gray, Asa, mentioned, 240, 435; books by, 442, 443, 447.
 Gum on buds, 54.
 Gynæcium, 139.
 Gymnosperms, 309.

 Habit, 388.
 Hackel, book by, 230.
 Hair-grass, 337.
 Hair on buds, 54.
 Halophytic, 413.
 Haw, 12, 13.
 Haws, germination, 339.
 Hawthorn, fruit, 293; germination, 339.
 Hazel, catkins, 157, 160.

(Numbers refer to pages)

- Hazels, 281, 284.
 Head, 165, 190, 196; of rye, 227.
 Heaths, anthers of, 148.
 Heartseed, 268.
 Heart-shaped, 118.
 Helicoid cyme, 195.
 Heliotrope, inflorescence, 195.
 Heliotropes, 222.
 Heliotropism, 330.
 Hemerocallis, 362.
 Hemlock knot, 22.
 Hen-and-chickens, 355.
 Henbane, fruit, 262.
 Hepatica, akene, 251, 276; blooming of, 414; flower, 131, 139, 145, 153, 183, 188; peduncle of, 163; phenology, 417; sleep of, 404.
 Herbarium, 437, 443.
 Herbs, 388, 393.
 Hermaphrodite, 139.
 Heterogonous, 240.
 Heterostyled, 240.
 Hexagynia, 433.
 Hexamorous, 214.
 Hibiscus, flower, 209; fruit, 265.
 Hickory, habit, 391; inflorescence, 161, 163, 306; nuts, 281, 285; twigs, 42, 57.
 Hicoria glabra, 44; microcarpa, 44; ovata, 44.
 Hilum, 332.
 Holly, phyllotaxy, 68.
 Hollyhock, flower, 209.
 Hollyhocks, leaf-scars, 42; renewing, 388.
 Homology, 53.
 Honey, 237.
 Honey locust, 39; fruit, 269; leaves, 130.
 Honeysuckle, 57, 60, 63, 64; flower, 237; stamen, 150; Tartarian, 39; classification, 326.
 Hoofs, seeds on, 338.
 Hooks for climbing, 401; on seeds, 338.
 Hop, climbing of, 396, 402.
 Hop-tree, fruit, 271.
 Hornbeam, catkin, 158.
 Horse-chestnut, 11, 15, 59, 64; germination, 328; inflorescence, 196; phenology, 417.
 Horse-radish, 376, 377; leaves, 87; roots of, 393.
 Horses, carry seeds, 338.
 Host, 407.
 House-leek, 325, 369; phyllotaxy, 68.
 Howell, book by, 443.
 Huckleberry, anther of, 148.
 Humming-birds, 237.
 Husk-tomato, fruit, 279.
 Hyacinth, double, 206; flower, 186.
 Hydrangea, inflorescence, 195; neutral flowers, 179.
 Hydrophytic, 413.
 Hyphæ, 351.
 Hypocotyl, 334.
 Hypogeal, 328.
 Hypogynous, 152.
 Ice-plant, 406.
 Impotent pollen, 235.
 Indeterminate growth, 14, 189.
 Indian corn: see Corn.
 Indian currant, 381.
 Indian pipe, 408.
 Indian turnip, 169.
 Indusium, 343.
 Inferior ovary, 151.
 Inflexed vernation, 59.
 Inflorescence, 162, 196.
 Ink, for marking roots, 322.
 Innate anther, 147.
 Insectivorous plants, 99, 405.
 Insect-pollination, 234, 236.

(Numbers refer to pages.)

- Insects and flowers, 137, 237.
 Interpretation of nature, 448.
 Introrse anther, 148.
 Involucel, 191.
 Involucre, 155.
 Involute, 57.
 Iris, flower, 152, 187; rhizome, 362.
 Isomerous flowers, 185.
 Ivy, 87, 400, 401; poison, 88, 414; roots, of, 374.
 Jack bean, 268.
 Jack-in-the-pulpit, 169.
 Jagged leaves, 119.
 Japanese ampelopsis, 400.
 Japan plum, 282, 396.
 Japan walnut, 39.
 Jeffersonia, anther of, 149; fruit, 263, 278; leaf, 89.
 Jewel-weed, 268.
 Jimson-weed, fruit, 265, 275.
 Juneberry, dispersion, 338; fruit, 293; twigs, 37.
 June-grass, conquest by, 383; flower, 227; panicle, 192, 193.
 Juniper, 310.
 Jussieu, 433.
 Kerner, book by, 447.
 Key-fruits, 270, 337.
 Kinds of plants, 425.
 Kinships of flower, 197.
 Knobel, books by, 443.
 Knot-holes, 21.
 Knots, 21.
 Label, 439.
 Labiate flowers, 184.
 Lady's-slipper, 222.
 Lamellæ, 348.
 Laminæ, 355.
 Lamson-Scribner, book by, 230.
 Lantern, in garden, 404.
 Larch, catkins, 307; leaves, 107.
 Larkspur, double, 206; fruit, 270, 276.
 Lawns, weeds in, 338, 411.
 Layers, 367.
 Leaf-bud, 5.
 Leaf-cutting, 377.
 Leaf-idea, 108.
 Leaflet, 87.
 Leaf-prints, 442.
 Leaf-scars, 38, et seq.
 Legume, 208, 261.
 Legumes, classification, 326.
 Leguminosæ, 208, 269, 402, 405.
 Lemna, 219.
 Lettuce, breeding of, 418; florets, 183.
 Lanceolate, 116.
 Lichen, 409.
 Lichens, 352.
 Ligustrum vulgare, 417.
 Lilac, duration of, 386, 388; fruit, 263; inflorescence, 196; phenology, 417; stamen, 150; statue, 389; suckering, 370; veneration, 58.
 Lilacs, shoots of, 11, 12.
 Lilies, classification, 327; duration of, 386; leaf-scars, 42; phyllotaxy, 69.
 Lily, anther, 147; Easter, 353; flower, 152, 185; fruit, 265; stamen, 150; tiger, 355.
 Lily-of-the-valley, 222; flower, 186; raceme, 189; rhizome, 362.
 Limb, 134.
 Linden, inflorescence, 193.
 Linear, 118.
 Linnæus, 428, 430, 432, 433; leaves, 119; veneration, 61.
 Linum, 240.
 Live-for-ever, phyllotaxy, 68.
 Live-oak, leaves, 122.
 Liverwort, flower, 131.
 Lobes, 87.
 Locel, 147.

(Numbers refer to pages.)

- Locellus, 147.
 Locule, 141, 146.
 Loculicidal, 264.
 Locust, flower, 207; fruit, 269; honey, 39; honey, leaves, 130; movement in, 402.
 Lodicule, 227.
 Lombardy poplar leaf, 79.
 Long-styled, 240.
 Loquat, 282.
 Love-in-a-mist, 270.
 Lubbock, books by, 336, 447.
 Lupine, movement in, 402.
 Lycaste, 226.
 Lycopodium, 347.
 Lythrum, 240.

 MacMillan, essay by, 414.
 Macrosporanguim, 311.
 Macrospore, 311.
 Macoun, book by, 443.
 Maidenhair fern, 342.
 Maize: see Corn.
 Male flowers, 139.
 Mallow family, 209.
 Mallows, 209; movement in, 403.
 Malus coronaria, 431.
 Mammals, carry seeds, 338.
 Mandrake, leaf, 114; ovary, 143; rhizome, 362.
 Mangrove, 371.
 Manuals, 442.
 Maple, blooming of, 414; branches, 17, 43; flowers, 219; fruit, 270; inflorescence, 196; leaf, 110, 113; leaves, 81; shoot, 51, 54, 58, 64; stature, 388, 394.
 Maples, species of, 429.
 Marguerite, leaves, 129.
 Marigold, 183.
 Marsh, book by, 414.
 Marsh-marigold, fruit, 276.

 Masters, books by, 199, 447.
 Matthews, books by, 289, 443.
 Maurandia, 247.
 May-apple, anther of, 149; leaf, 114; ovary, 143; rhizome, 362.
 Mayflower, 240, 390; phenology, 417; stature, 390.
 May-pop, 296.
 Meadows, weeds in, 338, 384, 413.
 Medlar fruit, 293.
 Melon, flowers, 164; fruit, 295.
 Member, 109.
 Merous, 214.
 Mesophytic, 413.
 Micropyle, 332.
 Microspore, 311.
 Mid-styled, 240.
 Mignonette, 222; fruit, 266, 270.
 Mildew, 351.
 Milk in cocoa-nut, 334.
 Milkweed, flower, 243.
 Mimosa pudica, 405.
 Mint, fruit, 253.
 Mints, leaf-scars, 42.
 Missing links, 436.
 Mistletoe, 406; seeds of, 338.
 Mitchella, 240.
 Mock-orange, 417.
 Mold, 351.
 Monadelphous, 208.
 Monocotyledon, 325.
 Monœcious, 170.
 Monopetalous, 184.
 Monstrosity, 99.
 Moonseed, leaf, 114.
 Morello cherry, 19.
 Morning-glory, and dodder, 407; climbing of, 396, 402; fruit, 265; seed of, 335.
 Morphology, 52, 53.
 Mosses, 346, 347, 352.
 Moss, on trees, 409; Spanish, 410.

(Numbers refer to pages.)

- Moths, 236.
 Mountain ash, fruit, 293.
 Mounting plants, 442.
 Movements of plants, 402.
 Mueller, book by, 242.
 Mulberry, fruit, 303; leaves, 124; phyllotaxy, 65.
 Mullein, duration of, 386; fruit, 265; growth of, 14; leaf, 110.
 Multilocular, 142.
 Multiple fruits, 305.
 Multiternate, 95.
 Mushrooms, 347.
 Muskmelon, fruit, 296.
 Mustard, anther, 147; classification, 326; family, 209, 262; flower, 132, 139, 145, 183; fruit, 262, 269; ovary, 142; receptacle, 150, 305.
 Mycelium, 349.
 Myriophyllum, 357.
 Myrtle, crape, 212.
 Nails in trees, 7, 24.
 Naked flowers, 139.
 Names of plants, 427.

 Narcissus, flower, 152, 186.
 Nasturtium, climbing, 401, 402; leaf, 114.
 Natural selection, 418.
 Nature, interpretation of, 448.
 Navel orange, 303.
 Nectar, 237.
 Nectary, 237.
 Needle-shaped, 118.
 Negundo, fruit, 271.
 Neutral flowers, 179.
 Newell, books by, 447.
 Newhall, books by, 289, 443.
 Nigella, fruit, 270.
 Nightshade, family, 209, 274; fruit, 275.
 Node, 47.

 Nomenclature, 427.
 Nubbins, 254, 255, 311.
 Nut, 281.

 Oak, apples, 285; branches, 15, 43; catkins, 157, 161; family, 284; knot, 21; leaves, 80, 88, 122; stature, 388, 394.
 Oaks, acorns, 281, 284; associates of, 413; leaf-casting, 43.
 Oats, 230; dispersion, 338.
 Oblanceolate, 118.
 Oblong, 117.
 Oblong-lanceolate, 117.
 Obovate, 118.
 Obtuse, 118.
 Ocrea, 113.
 Odors and insects, 236.
 Ecology, 413.
 Offset, 355, 369.
 Old-man-and-woman, 355.
 Oliver, book by, 447.
 Onion, bulbs, 354; germination, 323; seed, 334.
 Onions, propagation of, 358.
 Ontogeny, 341.
 Operculum, 347.
 Orange, fruit, 274, 303; leaf, 100; seed of, 335; stamen, 150.
 Orbicular, 118.
 Orchard fruits, 326; plants in, 384.
 Orchard grass, roots of, 393.
 Orchids, 222, 242; classification, 327; parasites, 409.
 Order, 209.
 Organ, 109.
 Organic compounds, 423.
 Osage orange, phyllotaxy, 68.
 Osiers, propagation, 368; twigs, 9.
 Oval, 118.
 Ovary, 133.
 Ovate, 117.

(Numbers refer to pages.)

- Ovule, 311.
 Oxalis, 240; dehiscence, 268; movement in, 402, 403, 406.
 Oxalises, 222.
 Ox-eye daisy, 177.
 Oxygen, 423.
 Oysters on trees, 374.

 Pæony, fruit, 276.
 Painted-cup, 156.
 Palmate, 87.
 Palmer, book by, 350.
 Palmetto, 42; vernation, 59.
 Palms, classification, 327; leaf-scars, 42; phyllotaxy, 68.
 Panicum capillare, 337.
 Pans for seeds, 330.
 Pansy, 210, 222.
 Paper model of leaves, 121.
 Papilionaceous, 207.
 Pappus, 174.
 Parasite, 351, 406.
 Parietal placenta, 143.
 Paris daisy, leaves of, 129.
 Parsley tribe, 190.
 Parsnip, duration of, 387; inflorescence, 190; tubers, 364.
 Passion-flower, 209, 217, 295.
 Partridge-berry, 240.
 Pea, climbing, 402; family, 208, 269; flower, 207; fruit, 261, 268; germination, 323, 328; leaf, 97.
 Pea, sweet, flower, 207, 240.
 Peach, fruit, 256, 257, 277; phenology, 417; plum on, 379; seed of, 335; stature, 389; twigs, 32 et seq., 49; vernation, 58.
 Peanut, fruit, 269.
 Pear, bud on pedicel, 199; fruit, 256, 293; leaf-scales, 54; on quince, 379; phenology, 417; spur, 28; twigs, 43.
 Pecan, seed of, 335.
 Peck, writings of, 350.
 Pedagogics, 445.
 Pedicel, 162.
 Peduncle, 162.
 Peltate, 114.
 Pentamerous, 214.
 Pepino, seedless, 376.
 Pepo, 298.
 Pepper, flower, 188; fruit, 276.
 Peppermint, rhizome, 362.
 Pepper, red, duration of, 386.
 Peppers, cotyledons, 336.
 Perennial, 386.
 Perfoliate leaf, 111.
 Perianth, 134; forms of, 183.
 Pericarp, 252.
 Perigynium, 232.
 Perigynous, 152.
 Peristome, 347.
 Petal, 134.
 Petiole, 80; as tendril, 400.
 Petiolule, 85; as tendril, 400.
 Petunia, double, 206; fruit, 275.
 Phalænopsis, 226.
 Phanerogams, 346, 352.
 Phenology, 415.
 Philadelphia, 417.
 Phlox, dichogamy in, 235; fruit, 265.
 Phosphorus, 422.
 Phyllodium, 106.
 Phylogeny, 341.
 Phyllotaxy, 68; of flower, 197.
 Physalis, fruit, 279.
 Physiognomy, 411.
 Phytion, 380.
 Pickerel-weed, 240.
 Pie, cherry, 19.
 Pie-plant, leaf, 112.
 Pigweed, dissemination, 337; fruit, 262; associates of, 411; classification, 326; leaf-scars, 42.
 Pileus, 347.

(Numbers refer to pages.)

- Pine and poplar, 384.
 Pineapple, fruit, 304; seedless, 376.
 Pine, healing of wounds, 72; leaves, 106, 107, 118; pollination of, 236.
 Pines, associates of, 413; discussion of, 306; phyllotaxy, 68.
 Pink, flower, 152; tribe, 143; placenta, 143.
 Pinks, renewing, 388.
 Pinnæ, 91, 344.
 Pinnate, 88.
 Pinnule, 91, 344.
 Pipe-vine, 210.
 Pistil, 133; compound, 144.
 Pistillate, 139.
 Pit, 257.
 Pitcher plant, 99.
 Pitch-forks, 180, 338.
 Placenta, 143.
 Plaited, 59.
 Plane tree, 40, 161.
 Planting school grounds, 448.
 Plants, growing of, 448.
 Plantain, fruit, 262; phyllotaxy, 68; rattlesnake, 223; spike, 189.
 Plant-food, 424.
 Pllicate, 59.
 Plum, fertilization, 313; flower, 144, 152, 214; fruit, 256, 257; habit, 396; on peach, 379; ovary, 142, phenology, 407; phyllotaxy, 67; spur, 31.
 Plumule, 321.
 Plur-annual, 386.
 Plurifoliate, 95.
 Pod, compound, 263.
 Pods, 259.
 Pogonia, 224.
 Poinsettia, 156.
 Poison ivy, 88, 414; climbing, 401; plants, 350, 414.
 Poison sumac, 88, 414.
 Pollen, 134; influence on fruit, 311.
 Pollinating, 246.
 Pollination, 136, 234.
 Pollinium, 243.
 Polyanthus, 239.
 Polygala, 244.
 Polygamous, 170.
 Polygonum, 401.
 Polymorphism, 240.
 Polypetalous, 183.
 Polypetal, 215.
 Polysepalous, 184.
 Pome, 293.
 Pondweeds, 376.
 Pontederia, 240.
 Poplar, leaf, 79.
 Poplars, sex of, 163.
 Poplar succeeds pine, 384.
 Poppy, California, 403; fruit, 263.
 Portulaca, movement in, 403: see Purslane and Pursley.
 Potassium, 422.
 Potato-blight, 352.
 Potato, cuttings of, 377; duration of, 386; flower, 152; fruit, 275; phyllotaxy, 69; sweet, 363; tuber, 362.
 Potatoes, hill of, 366.
 Prepotent pollen, 235.
 Preserving of plants, 437.
 Pressing plants, 441.
 Prickles for climbing, 401.
 Prim. phenology, 417.
 Primrose, fertilization, 239; placenta, 143.
 Privet, phenology, 417.
 Privets, shoots of, 11.
 Procumbent, 390.
 Progressive inflorescence, 101.
 Propagating-box, 380.
 Propagation of plants, 316 et seq.
 Prostrate, 390.
 Proterandrous, 169.
 Proterogynous, 169.

(Numbers refer to pages.)

- Prunus serotina*, 417; *Virginiana*, 417.
 Pseud-annual, 387.
Pteridophytes, 346, 352.
 Pulse, 208.
 Pumpkin, family, 209, 295; flower, 152; fruit, 295.
 Pumpkins and corn, 384.
 Purslane, fruit, 262; movement in, 403, 406.
 Pussley, fruit, 262; movement in, 403, 406.
 Pussy willows, 138, 171.
 Putamen, 257.
 Putty-root, 223.
Pyrus coronaria, 431; *Japonica*, 417.
Pyxis, 263.
 Quack-grass, duration of, 386; rhizome, 361.
 Quadrifoliate, 95.
 Quadrilocular, 142.
 Quadriseriate flower, 139.
Querl, 400.
 Quinate, 89.
 Quince, fruit, 293; leaf, 110; phenology, 417; pear on, 379; shoot, 55.
 Quinquefoliate, 95.
 Quinquelocular, 142.
 Raceme, 189.
Racheola, 232.
Rachis, 88, 345.
 Radicle, 334.
 Radish, duration of, 387; fruit, 262; germination, 330; tubers, 364.
 Ragweed, florets, 183; in orchards, 384.
Ranunculaceæ, 252, 276. [390.
 Raspberries, dispersion, 338; habit, Raspberry, fruit, 255, 305; phenology, 417; propagation, 368; shoots, 55.
 Rattlesnake plantain, 223.
 Ray flowers, 179.
 Receptacle, 150.
 Red-bud, blooming of, 414.
 Red cedar, leaves, 125.
 Red pepper: see Pepper; fruit, 276; leaves, 116, 117.
 Red-root, fruit, 262.
 Reed, leaf-scars, 40.
 Reflexed vernation, 59.
 Reinforced flowers, 152, 163; fruits, 278, 284.
 Reniform, 119.
 Repand, 119.
Retinospora, leaves, 125.
 Retuse, 118.
 Rheumatism-root, 263.
 Rhizome, 361.
 Rhododendron, bud, 52; leaf, 110.
 Rhubarb, leaf, 112; vernation, 63.
 Rice, 230; wild, 339.
 Rings of growth, 7.
 Roadside, flora of, 411.
 Robbers, 406.
 Robinson, book by, 347.
 Root-climbers, 401.
 Root, growth of, 321.
 Root-hairs, 329.
 Root systems, 393.
 Roots as runners, 370.
 Rootstocks, 358.
 Rosaceæ, 209.
 Rose, double, 206; family, 209, 254, 277.
 Rose, moss, 403.
 Rose, stamen, 150.
 Roses, 222; classification, 326; duration of, 386; shoots of, 11.
 Rosette, 355.
 Rotate corolla, 185.
Rudbeckia, 177.
 Runners, 367.
 Rushes, classification, 327.

(Numbers refer to pages.)

- Russian thistle, leaf, 103; spread of, 337.
 Rye, 227, 230.
- Sage, anther of, 149; scarlet, 156.
 Sagittaria, 191.
 Sagittate, 119.
 Salix, discolor, 44; rostrata, 44.
 Salsify, duration of, 387; florets, 183; roots of, 393; tubers, 364.
 Samara, 271.
 Sambucus, 417.
 Sand-bur, 338.
 Saprophyte, 351, 406.
 Sap-wood, 424.
 Sarcocarp, 257.
 Sarcodes, 409.
 Sassafras, leaves, 124.
 Savin leaves, 125.
 Scape, 188.
 School grounds, 448.
 Scirpioid cyme, 195.
 Sclarea, 156.
 Scouring-rush, 346.
 Scramblers, 401.
 Scullion, 355.
 Sea-beans, 339.
 Sea-weeds, 352.
 Sedge, layer of, 367.
 Sedges, 164, 230; classification, 327; leaf-scars, 42; rhizome, 362.
 Seed, 252, 334; leaves, 320.
 Seed-pod, 132, 133.
 Seedlings, 336.
 Seeds, dispersion of, 336.
 Segments, 87.
 Selaginella, 346.
 Sensitive fern, 343.
 Sensitive plant, 405.
 Sepal, 135.
 Septicidal, 264.
 Septifragal, 265.
- Serrate, 119.
 Sessile, 83.
 Setchell, book by, 447.
 Sexes in plants, 139, 156.
 Shadberry, fruit, 293.
 Shad-bush, twigs, 37.
 Sheath, 112.
 Sheep, browsing by, 412; carry seeds, 337.
 Shield-fern, 343.
 Short-styled, 240.
 Shrubs, 10, 390.
 Shrub-trefoil, fruit, 271.
 Silicle, 262.
 Silicon, 422.
 Silique, 262.
 Simple leaf, 86.
 Sinistorse, 398.
 Sinuate, 119.
 Sinus, 119.
 Skunk-cabbage, 169, 411.
 Sleep of plants, 403.
 Smartweed, leaf, 112; scrambling, 401.
 Smilacina, 360.
 Smilax, flower, 188; leaves, 122, 124; of florists, 104; wild, 41.
 Smoke vine, 214.
 Snails, pollination by, 245.
 Snowball, inflorescence, 197; ventral flowers, 179; stature, 389.
 Snow-on-the-mountain, 219.
 Snow-plant, 409.
 Societies of plants, 410.
 Sodium, 422.
 Solanaceæ, 209, 274.
 Solanum, fruit, 275.
 Sorghum, 230.
 Sorrel, associates of, 413; leaf, 113.
 Sorus, 343.
 Southworth, book by, 230.
 Spadix, 169.
 Spalding, book by, 447.

(Numbers refer to pages.)

- Spanish moss, 410.
 Spathe, 269.
 Spatulate, 118.
 Spawn, 349, 359.
 Specialization, 225.
 Species 425.
 Specimens making, 437.
 Speedwell, 96.
 Spermatophyte, 310, 352.
 Spike, 65, 189.
 Spikelet, 228, 233.
 Spines on seeds, 338.
 Spireas, shoots of, 11.
 Spore, 342, 345, 346.
 Sporangium, 342.
 Spore-case, 342.
 Spore-print, 349.
 Spring, coming of, 414.
 Spruce, leaves, 107, 118, 125.
 Spruces, catkins, 306.
 Spurge, 218.
 Spurs, 25.
 Squash, family, 209, 295; flower, 152, 163, 184; fruit, 295; germination, 316.
 Squirrel-corn, 89; flower, 214.
 Squirrel in knot-hole, 23.
 Stag's-horn fern, 410.
 Stamen 134.
 Staminate, 139.
 Staminodium, 202.
 Standard, 207.
 Stature of plants, 388.
 Sterculia, carpels, 202.
 Sterile flowers, 39.
 Stick-tights, 180, 253, 280, 337.
 Stigma, 133.
 Stipel, 85.
 Stipules, 80.
 Stock, fruit of, 262.
 Stolon, 368.
 Stone-fruit, 257.
 Stipe, 342, 347.
 St. John's-wort fruit, 265.
 Strawberry, fruit, 253, 274, 305; hull of, 153, 155; inflorescence, 197; phenology, 417; runner, 368; sex of, 163; stamen, 150.
 Strawberry tomato, fruit, 279.
 Struggle for existence, 15, 381, 410.
 Style, 133.
 Sucker, 11, 370.
 Suffrutescent, 393.
 Suffruticose, 393.
 Sugar cane, 230.
 Sumac, 13; leaf-scar, 40; poison, 88, 414 stature, 389.
 Sunflower, 79, 82, 183; phyllotaxy, 68 receptacle, 305.
 Superior ovary 151.
 Supernumerary buds, 39.
 Suture, 261.
 Swallows, 171.
 Sweet pea, flower, 207, 240; seed of, 335.
 Sweet potato, 363; and dodder, 407.
 Sycamore, 40, 161.
 Syconium, 305.
 Symmetrical flowers, 185.
 Synanthous, 170.
 Syncarpous, 251.
 Syringa, 417.
 Tamarack, leaves, 107.
 Tansy, 183.
 Tap-root, 393.
 Tartarian honeysuckle, 39.
 Tassels of corn, 166.
 Teachers suggestions for, 445.
 Teasel, 181 duration of, 386.
 Tendrils, 398; on leaves, 97, 108.
 Tension, plants live under, 382.
 Teratology, 199.
 Terminology, 95.

(Numbers refer to pages.)

- Ternate, 89, 95.
 Tetramerous, 214.
 Tetrandria, 433.
 Thallophtes, 352.
 Thermometer, 414.
 Thistle, dispersion, 337; leaves, 86.
 Thistles, florets, 183; growth of, 14.
 Thyse, 196.
 Tiger lily, bulblets, 357.
 Tips of raspberry, 368.
 Toad-flax, fruit, 265.
 Toadstool, 349.
 Tobacco, fruit, 275.
 Tomato, fruit, 274, 300; leaves, 92, 126;
 pollination of, 312.
 Tomatoes, cotyledons, 335.
 Torus, 150.
 Trees, duration of, 386; what are, 389.
 Trefoll, shrub, 271.
 Tri-compound, 91.
 Trifoliate, 95.
 Trilocular, 142.
 Trimerous, 214.
 Trimorphic, 240.
 Tripalmate, 95.
 Tripinnate, 95. [114.
 Tropæolum, climbing, 401, 402; leaf,
 Triserial flower, 139.
 Triternate, 95.
 Trumpet-creeper, 374, 401.
 Trumpet-shaped corolla, 185.
 Truncate, 118.
 Trunks, why cylindrical, 69.
 Tubercle, 363.
 Tubers, 362; perpetuation by, 387.
 Tubular corolla, 185.
 Tulip, anther, 147; double, 204, 206;
 flower, 139, 185, 188; fruit, 265;
 ovary, 142, 145.
 Tulip tree, leaves, 124; vernalion, 59.
 Tumble-weeds, 337.
 Tunicate, 355.
 Turban squash, 296.
 Turnip, battle for life, 382; duration
 of, 287; fruit, 262; roots of, 393;
 tubers, 363.
 Twiners, 398.
 Umbel, 190.
 Umbellet, 191.
 Underwood, book by, 346.
 Undulate, 119.
 Unifoliate, 95.
 Unilocular, 142.
 Uniserial flower, 139.
 Vaginate, 112.
 Valvate æstivation, 183.
 Valve, 262.
 Vanilla, 223.
 Variation, starting of, 419.
 Varieties, 426.
 Varnish tree, 202.
 Vascular cryptogams, 346.
 Vasculum, 440.
 Veil of mushroom, 348.
 Venation, 96.
 Ventral, 260.
 Verbena, stamen, 150.
 Vernation, 61.
 Veronica, 96.
 Versatile anther, 147.
 Verticillate, 65.
 Vexillum, 207.
 Violaceæ, 210.
 Violet, dehiscence, 268; double, 206;
 flowers, 209, 222.
 Virginia creeper, 84, 400, 414.
 Vitis, description of, 428; *Labrusca*,
 428.
 Volva, 350.
 Wallflower, fruit, 262.
 Walnut, catkins, 162; fruit, 285; leaf,
 92; twigs, 39, 55.

(Numbers refer to pages.)

- Warming, book by, 413.
 Water, carries seeds, 339.
 Water-lily, anther, 147, 149; flower, 199; fruit, 263; leaf, 114; rhizome, 362.
 Watermelon, fruit, 295; querl, 400.
 Weather Bureau, quoted, 415.
 Weed, book by, 447.
 Weeds, 338, 383.
 Wheat, 230; cockle in, 338; leaf, 80 111; seed of, 335; weeds in, 278.
 Wheel-shaped corolla, 185.
 White cedar, leaves, 125.
 White-wood, 59.
 Whorl, 65.
 Wild Goose plum, 313.
 Wild rice, 339.
 Willis, book by, 447.
 Willow, anther, 147; flower, 138, 139; leaves, 82; phenology, 417; twigs, 44; veneration, 61.
 Willows, cuttings of, 374; pussy, 138, 171; sex of, 163; shoots of, 11.
 Wilting, 403.
 Wind-flower, 153.
 Wind-pollination, 234, 236.
 Wings of flower, 207.
 Wistaria, dehiscence, 268.
 Witch-hazel, 280; suckering, 370.
 Woodpecker in knot-hole, 23.
 Wood-pile, 25.
 Wood-sorrel, movement in, 402.
 Woods, plants in, 413.
 Wool on buds, 54.
 Wormwood, 183.
 Xerophytic, 413.
 Yellow bell, 87.
 Yew, 310.
 Youmans, book by, 447.
 Zigzag growth, 13.
 Zinnia, 182.



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